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MEDICAL EFFECTS OF ATOMIC BOMBS

The Report of the Joint Commission for the Investigation of the Effects of the Atomic Bomb in Japan; Volume II.

By

Ashley W. Oughterson
George V. LeRoy
Averill A. Liebow
E. Cuylor Hammond
Henry L. Barnett
Jack D. Rosenbaum
B. Aubrey Schneider

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Army Institute of Pathology

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C O N T E N T S

Section 4H

MATERIALS AND METHODS

Prepared by Averill A. Liebow, Lt. Col., MC

The Hiroshima section of the Joint Commission, consisting of 6 medical officers, 4 enlisted men and some 25 Japanese physicians, reached Hiroshima by air on 12 October 1945. The city still was in the process of drying from the disastrous typhoon of 17 September and the clouds of the succeeding tempest of the first week of October were just clearing. Headquarters were established at the Ujina Branch Hospital of the Hiroshima First Army Hospital some 4300 meters from the point above which the bomb exploded. This hospital comprised the converted residential quarters of the Daiwa Rayon Mill. Laboratory, office, and clinic rooms were procured and arrangements were made with the military and prefectural authorities to supply rations and quarters for patients that were to be referred for study from other institutions and from outpatient clinics. Approximately 75 patients were already in the hospital when the Joint Commission arrived, in the care of Japanese military physicians who extended every courtesy.

Fortunately the electric circuits had been re-established after their interruption by the typhoon, and plenty of water was available. All apparatus, chemicals, record sheets, stenographic equipment, rations, and three 1/4 ton vehicles had been brought in by air. Staining solutions and a few standard reagents had been prepared at Tokyo Imperial University while the Commission was awaiting passage to Hiroshima.

Four main channels of investigation were pursued, more or less simultaneously:

1. Review of existing records and collection of specimens.
2. Clinical and laboratory studies.
3. Collection of data for obtaining estimates of the population and casualties.
4. Analyses of the factors in protection.

Appropriate data thus collected was subjected to statistical analysis as presented in Section 9.

1. REVIEW OF EXISTING RECORDS AND COLLECTION OF SPECIMENS

A. Use of standard record forms and maps.

A record form containing essential personal and clinical data was designed for use in transcribing old records as well as for the purpose of the Commission's original observations. Special emphasis was put on the accurate recording of factors of distance, and shelter. As an aid in attaining this objective, maps of the city which had concentric circles drawn about the center of the explosion were used. These were always in the possession of the physicians while obtaining information from the patients and proved to be extremely valuable. The data secured by these means were employed for the statistical analysis to be presented in Section 9, where also appears a detailed description of the record form. On these forms were entered not only information from patients seen by the Commission, but also data from records already available.

B. Existing Japanese Records, Reports, and Specimens.

One of the first tasks of the Commission was to collect all existing data and materials and to establish an estimate of their reliability. Whatever proved to be reliable after investigation was transferred to the records of the Commission. In each instance, the transferral of information from the Japanese to American records was accomplished with the aid of English-speaking Japanese physicians, whose integrity had been established by previous personal contact, working directly with the Americans. Thus, accuracy was improved not only by linguistic and medical vigilance but also by opportunity to establish by direct questioning the exact meaning which might be lost if non-professional translation services were utilized. The attempt was not to ask leading questions and to embody in the translated records only actually and unequivocally recorded data. In this manner, old hospital records of the Ujina Hospital, Red Cross Hospital, Post Office. (Teishin byoïn) Hospital, and Kusatsu Prefectural Hospital were transcribed. At the completion of clinical work in Hiroshima and adjacent cities, the records of the Iwakuni, Kure Naval, Saijyo, Okayama Military and Okayama Medical School, Takatsuke Medical School, Kobe, Osaka, Kyoto Imperial University Medical School, and Kyoto Prefectural Hospitals, and of the Tokyo Imperial University were reviewed. In each instance, the actual clinical record and not a summary or chart was the source of the information.

C. Review of Japanese Reports:

The Japanese, keenly aware of the necessity of medical investigation of the casualties had sent several "research parties" to Hiroshima before the arrival of the Joint Commission. Certain distant hospitals which had re-

ceived evacuees from the city in some instances also conducted their own studies. Reports were issued from time to time by all of these investigators. Texts of completed and projected works were collected by Professor Masao Tsuzuki, who furnished lists and copies of the reports as they appeared, to American members of the Joint Commission. The most important of these are summarized in appendix 1 of this section. They will be referred to in the text thereafter by number as they appear in the appendix. To a certain extent they overlap the data summarized in the present report since the original records on which they are based were also reviewed by the Joint Commission. There is much, however, concerning clinical detail in the earliest cases which is not otherwise available.

D. Autopsy Specimens:

The pathologic descriptions and analyses are largely of material supplied by Japanese pathologists. This had been widely disseminated throughout the country and the collection of adequate specimens after the devious process of charting their whereabouts, required rather extensive travel. Almost all of it was yielded willingly and in good faith. Some came to hand only after various complex native academic and political intrigues had been untangled.

Much of the tissue thus collected had been rendered unsuitable by poor fixation, or by the use of formalin of inadequate strength. This chemical had been almost unobtainable in Japan and was used very sparingly by the pathologists. The autopsies performed by the group from the Tokyo Imperial University and the Military Hospital of Ujina were carried out almost immediately after the death of the patient, as were those performed by the

Commission. Some of the other material shows too much postmortem change for interpretation.

The gross notes were translated directly to members of the Commission of English-speaking Japanese pathologists. They are for the most part brief and stilted, but in general proved to be reasonably accurate when it was possible to corroborate the description by inspection of the organs themselves. Microscopic sections were obtained from the Japanese whenever possible even when gross material was still available. The latter was brought back to U. S. Army installations and was prepared for microscopic study at the Army Institute of Pathology in the case of the Hiroshima specimens, and at the 18th Medical General Laboratory at Hawaii in the case of the tissues from Nagasaki. Material from the latter city was also prepared under the auspices of the U. S. Navy and is stored at the Medical Center, Naval Medical Research Institute in Bethesda, Maryland.

The protocols, tissue and slides are preserved in the Army Institute of Pathology. The original Japanese sections were often from better fixed material since the residual gross tissue was usually poorly preserved in the form of over-large blocks in dilute formalin or in formalin that had been used previously.

At the Army Institute of Pathology the accession number 158930 has been assigned to all of this material. Each autopsy has been given a "key number" under the general accession number by which the protocols and tissues are filed. A cross-index and guide to all of the material and records has been prepared and is available at the Institute.

2. CLINICAL AND LABORATORY STUDIES

A. Patients in hospital.

When the Atomic Bomb Commission reached Hiroshima on 12 October 1945, the patients were found under treatment at several hospitals. The immediate problem was to place them under the direct surveillance of the Commission. For this purpose, teams of American and Japanese were organized to study these cases in detail and to observe and record whatever manifestations of disease were still in evidence. Acute manifestations had largely disappeared by the middle of October and none with petechiae were seen. The information concerning earlier cases consequently is based entirely upon Japanese observations.

The patients at the Ujina Military Hospital, then under the control of the First Military Hospital, were the first to come under study. Then came those at the Kusatsu Prefectural Hospital, Red Cross Hospital, Communications Department (Post Office) Hospital, Saijyo Sanatorium, and Iwakuni Hospital.

B. Clinic Patitments.

After this phase of the work, negotiations were made to establish clinics at the Post Office Hospital, which cared not only for its own employees, but also for others who had been injured, particularly those in Usida District. This clinic was maintained continuously until late in November. Here came under study and treatment patients in a stage of recovery who had previously been acutely ill and whose earlier records were available.

C. "Sampling" Study.

After the initial phase of hospital work had been established, an attempt was made to perform a "sampling" study. This was designed to obtain

for examination not only patients who had been injured and who had become ill as a result of the bombing but also healthy survivors from all zones. This was not truly a study of individuals representative of the population of each zone, since there was an obvious predominance of injured and ill who wished to avail themselves of the facilities of consultation and treatment afforded by the clinic. Healthy survivors who did come under the surveillance of these clinics, however, yielded excellent clues as to why they were unaffected, or apparently unaffected, by the bombing.

The method was to establish contact with some central agency in representative precincts, to explain to them the purpose of the work, to promise a certain amount of therapy, particularly dressings, and to arrange that they advise the population to meet at a certain time and place, usually a school. The necessity of obtaining not only sick but also apparently well individuals was stressed and the concentrically circled map was demonstrated to indicate what territory came within the sphere of investigation. Excellent cooperation was almost always obtained from the local police or administrative authorities. Appointments were made two days in advance of the time that the clinics were held. The aid of respected and influential Japanese physicians facilitated this liaison.

Each clinic team consisted of an American medical officer and one or two of the most competent Japanese physicians, each of whom was in charge of a team of four Japanese senior medical students or recent graduates. The personnel of the teams was kept constant so that the excellencies and shortcomings of each individual soon became apparent, thus affording opportunity of correction

by admonition and example. Each student's record was checked by the leading Japanese, who then brought all of the completed records for review, one by one, with the American medical officer in charge of the group. This systematic channeling of authority did much to improve the quality of the work.

During the course of the study, a distribution chart was maintained in order to assure a representative sample of individuals surveyed as far as geographic location was concerned. Plans were made according to the indications of this chart day by day.

Differentiating Schemes.

In order to differentiate the various types of cases, a consecutive numbering scheme was employed with special prefixes and suffixes to differentiate the types of cases. The first Hiroshima case was given the number 6001, since a block of 6000 numbers had been assigned to the parallel Nagasaki study. Actually, more than 6000 patients were studied in each city and the records were renumbered when brought back to the United States. The prefix "H" was used for hospital inpatients; those with the prefix "O" were outpatients seen in various clinics and those with the prefix "S" were individuals that came into the "sampling" survey. The suffix indicated the place of record. A list of these is appended (table 1), for the convenience of identifying the original records. This scheme proved useful since it was possible at once to identify the nature of the case and the place where observed.

Table 1 (Continued)

SUFFIXES

Kps	Kyoto Prefectural Medical School (Cases studied at Kyoto)
Kps-H	Kyoto Prefectural Medical School (Cases studied at Hiroshima)
Ku	Kaijin - Kai (Kure)
Kyoto	Kyoto University
M	Mitsubishi Hospital
N	Niho
Okayama	Okayama Medical School
Om	Okayama Military Hospital
On	Onaga
Ono	Ono Hospital
Osk	Osaka Medical School
Ot	Otake
Ou	Ouzu
P	Post Office Hospital
Pe	Early Post Office Cases
Pr	Prison
R	Red Cross Hospital (Hiroshima)
S	Saijyo
Sa	Second Army Hospital

Table 1 (Continued)

SUFFIXES

Takatsuke	Takatsuki Branch of the Osaka Medical Faculty
Tot	Tottori Army Hospital
U	Ujina Hospital
Uh	Usida
Uj	Ujina Public School #1
Us	Ujina Public School #2
Ush	Usida Hospital (Kyoto Research Committee Patients)
Ya	Yaga
Yo	Yokogawa

D. Laboratory Data:

Much of the laboratory data in the pages that follow were obtained in various Japanese medical laboratories before the Joint Commission began to function. In some instances, it was obvious from the results that the technical procedures were regularly in error and consequently the entire technical output of the laboratory concerned was disregarded except for slides and specimens that remained, and were subject to restudy by the Commission.

In the survey work of the Commission, the most commonly employed laboratory procedures were the following:

1. White blood cell count, differential, hemoglobin, blood protein. These were determined routinely in every fifth patient regardless of indications. The object was to collect data concerning exposed but asymptomatic individuals as well as from those who were ill.

Venipunctures were performed on all of these patients. Smears were made directly from the fresh blood and the remainder was brought to the laboratory in oxalated form for the determination of total protein and hemoglobin by the copper sulfate* method and for a white cell count. A chart, different from that which appears in the original method, was employed. This gives readings for serum proteins that are approximately 0.6 gram higher. When the hemoglobin was below 8 grams per cent, red blood counts and hemoglobin were usually also determined. In normals or near normals, the Sahli and copper sulfate method usually checked within 0.5 per cent but occasionally were off as much as 2 grams per cent.

*Simmons, J. S., and Gentzkow, C. J. Laboratory Methods of the United States Army. 5th Ed'n. Lea and Febiger, Philadelphia, 1944.

2. Price Jones curves were determined on some of the smears when they were brought back to the United States (See Section 6).

3. Reticulocytes were counted in brilliant cresyl blue preparations counterstained with Wright or Giemsa solution. The brilliant cresyl blue was spread on slides which were allowed to dry. The blood was then applied in a thin film, the slide was allowed to remain in a moist chamber for approximately 3 minutes, and then was counterstained.

4. Platelet counts. These were made in permanent smears which had been prepared by the method of Fonio-- by puncture of the finger through magnesium sulfate solution. The normal values by this method in Japanese subjects were said to range from 160,000 to 300,000, with an average level of 230,000.

5. The bleeding time was performed by the method of Duke using filter paper and ear blood, and the clotting time was estimated by the method of Sahli and Fonio--, using either glass slides or a watch glass and employing a drawn out glass rod as the "wire."

6. Bone marrow was aspirated with a #16 short needle. The sternum or a spinous process near its junction with the arch of a vertebra was the site of choice. The latter was commonly employed by Dr. Nakao of Tokyo Imperial University. It is done with the patient in the sitting position and has the advantage of concealing the large needle from the patient. Also it relieves him of the fear induced by pressure on the thorax, no matter how gentle. Little difficulty was encountered in obtaining satisfactory specimens of marrow which are entirely comparable to that obtained from the sternum. Very gentle suction with the syringe

was employed, to reduce the dilution factor as much as possible. The smears were immediately fixed in absolute methyl alcohol and stained either by the Giemsa or Wright-Giemsa methods. All preparations made by the Commission were by the latter method.

7. Sperm counts. The cooperation of Japanese patients was enlisted by explaining the medical indications or by the use of small gifts. The material was produced at the clinics by the friction method and was collected in test tubes and immediately examined for motility. Counts were made usually within 4 hours using a diluent consisting of 5% sodium carbonate solution containing 1% formalin and a standard hemacytometer.

8. Endometrial biopsies were obtained by ordinary curette in patients with amenorrhea. The work was performed by a special Japanese team under the supervision of Dr. Mitani and Dr. Iwai at the Red Cross Hospital. They obtained complete records of the menstrual histories and examined each patient gynecologically.

Other techniques used in Japanese Laboratories before arrival of the Joint Commission were as follows:

1. Sedimentation rate by the method of Westegren. Usually the one-hour reading was recorded or in some instances a curve was made with the final reading at 2 hours.

2. Icterus Index by the Meulengracht procedure.

3. Serum bilirubin by the method of van den Bergh

4. Urobilinogen by the method of Ehrlich.

5. The Takata-Ara reaction by the standard method as originally described.

6. Occult blood in feces, either by the benzidine or Guaiac methods. The latter which is known to be more specific gave results which were positive approximately one-third as frequently as the former.

7. Gastric juice was examined by the method of Katsch-Kalk.

8. The few blood cultures that were made were done by the inoculation of nutrient broth and also by the inoculation of a bile broth. The latter was employed particularly in the attempt at detection of typhoid bacilli.

9. Media used for stool cultures were the Endo plate and Conradi-Drigalski media.

10. The non-protein nitrogen was performed according to Kowarski* This requires some discussion since the results in the patients with radiation effects as tested late in September, 1945, were low. Three control levels that had been used at the time the method was first put into operation, approximately 10 September 1945, ranged between 25.0 and 26.7 milligrams per cent. A Somogyi filtrate followed by Nesslerization was employed. There was some question of the purity of the mercury used in preparing the Nessler reagent.

The methods used by the Kyoto research group were similar. In addition, serum proteins were determined by the Pulfrich refractometer.

* Klopstock, M., and Kowarski, A.: Praktikum der Klinischem, Chemischen, Mikroskopischen, und Bakteriologischer Untersuchungsmethoden, (Revised by Tillmanns and Ohnesorge). 1940. Japanese Edition.

E. Clinical and Laboratory Controls.

It was necessary to obtain background information for interpreting both clinical and laboratory information of this somewhat undernourished population living in a disorganized community where there was abundant opportunity for the spread of infectious diseases. Why no major epidemics were reported is a complete mystery, considering the hovels into which patients were crowded and the dubious sources of water that were employed. For these purposes, individuals situated at the periphery of the city would in some measure act as controls for those nearer the center: the factors of diet and infection can be assumed to have affected both groups equally.

Balanced control groups were established to a limited extent. The first consisted of employees of the railroad who had been at Ujina Base Office, 4.6 km distant, in comparison with employees who had been at work at the main station and associated yards, 1.8 km distant. Another group comprised students at the provisional Hiroshima High School near Kaitaichi who had been far from Hiroshima at the time of the bombing. These were compared with their fellows equal in age who had been closer to the center.

3. STUDIES OF POPULATION AND CASUALTIES

The important problems were to obtain an accurate estimate of the population of the city at the time of the bombing and an adequate statistical sample of survivors who could give trustworthy information concerning the disposition and fate of individuals. The ultimate purpose of the study was the construction of a curve showing the relation between the casualties and the distance from the bomb and the elucidation of the causes of the casualties. In the matter of sampling of the population, the Commission was

advised late in November, 1945, by Lt. Harold Nisselson, USNR, of the United States Strategic Bombing Survey. The actual work and much of the planning were performed by Captain (then 1st Lt.) Marvin E. Habel, FA, with the assistance of Dr. Motosaburo Masuyama, of the Institute of Statistical Mathematics of the Japanese Department of Education. A plan was submitted to The Chief Surgeon at GHQ, Tokyo, on 3 December 1945, which was approved. The group arrived at Hiroshima on 7 December 1945 and completed its mission on the 22nd. The methods employed in arriving at an estimate of the pre-raid population and of the casualties are presented in Section 10H.

Historically, the procedures just discussed actually were the last adopted. At the outset it was thought that the best method would be to analyze the casualties of various groups scattered about the city at known distances from the center. Data on the schools were collected for this purpose by various members of the Tokyo First Military Hospital who were stationed at the Ujina Hospital. They do not provide a representative sample of the population, but yield certain information of value.

Data concerning certain other specific groups whose conditions of exposure and subsequent fate were known, were also sought in an effort to analyze the various individual factors concerned in producing the total casualty rate. Such information was forthcoming inasmuch as certain villages and schools that had sent "patriotic workers groups" into Hiroshima on the day of the bombing had kept records that gave all the appearances of trustworthiness. These are also presented in Section 10H.

4. ANALYSIS OF FACTORS IN PROTECTION

The factors of protection against blast, heat and radiation sickness

were studied in the individual cases at the time the histories were taken and physical examinations performed. In patients who had been burned, clothing was collected and its color and cut were correlated with the location and character of the burn. Pertinent data are presented in Section 5H. In particular, an attempt was made to discover why certain persons escaped injury although close to the center. Such patients provided a clue to the study of larger groups, such as the high school girls in certain concrete shelters in the Chogoku Army Headquarters (Section 11H).

Teams were organized with the specific duty of collecting clinical data concerning people in specific buildings, of establishing their exact positions and of making measurements later to be used in filtration factors. 1st Lt. William Vance, SnC, of the 29th Malaria Survey Detachment at Kure, whose engineering talents came to light, was attached to the Commission for the purpose of determining certain measurements of buildings. Dr. Koiti Murati, the biophysicist, and Dr. Takeo Murai, with the cooperation of Japanese students, exhibited great ingenuity and industry in the study of buildings and in locating and interviewing survivors.

These various types of study were done in sequence only in a general sense. Actually, it was possible to proceed simultaneously with several phases of the examination.

Appendix 1 - Section 4H

ABSTRACTS OF JAPANESE REPORTS

Edited by Verne R. Mason, Col., MC

In this section are presented in brief the salient features of the most important reports concerning Hiroshima, of the Japanese investigators. Emphasis is placed on observations of early cases that could not be made by the Joint Commission itself, on other material of interest that does not appear in the body of this report, and on certain matters with which the Joint Commission is not in agreement but which may be worth recording. The translated Japanese reports are available in full at the Army Institute of Pathology and are filed with other materials of this study.

1. Army Medical College and First Tokyo Army Hospital: "Medical Report of the Atomic Bombing in Hiroshima."

This is a comprehensive report dealing largely with 712 patients seen in the following Army hospitals by Japanese medical officers: First and Second Hiroshima, Fukuyama, Okayama and Himeji. The report was compiled by members of the Army Medical College in Toyko and the First Tokyo Army Hospital who proved to be among the best trained physicians encountered by the Commission in Japan. Their observations were made between 8 August, when some of them arrived in Hiroshima to work in the aid stations, and the middle of November, 1945. It is the result of the cooperative efforts of these officers together with those of the members of the faculty of the Tokyo Imperial University. Many of the latter were later with the Joint Commission. The original clinical records were made available to the Joint Commission and the essential data were transcribed to the standard form and have been made part of the material for the statistical analysis. Major Misono and other moving spirits in the

Japanese enterprise worked directly with the Commission in accomplishing this transfer. The tabulated data, as summarized in the final report of the Army Medical College, was found to be completely accurate in every detail when checked against the original records. For this reason, as well as on the basis of the personal contacts with the medical officers of the Army Medical College, much reliance is placed on the descriptions by these observers of the casualties in the early weeks. The data collected during the week before and after 1 September 1945 when the signs and symptoms of radiation effect were most spectacular are particularly well documented. Numerous hematological and pathologic specimens collected largely by the members of the Tokyo Imperial University at that time were made available to the Commission. They were among the most excellent technical preparations that became available. Another series of bone marrow aspiration biopsies was performed by Professor Morita of Yamanashi Medical School late in September. These were also reviewed. Among the laboratory procedures, in addition to ordinary hematological work including bleeding and clotting time, platelet counts, fragility tests, bone marrow punctures, were the following; Determination of sedimentation rates, incterus index, serum bilirubin, urobilin and urobilinogen (in addition to ordinary urinalyses), Takata-Ara reactions, blood chlorides and NPN, determination of occult blood in feces, parasitological examinations, stool cultures, blood cultures, and examinations of gastric juice. All evidence indicated that the work was carefully done.

Three series of necropsies were performed. The first, a group of 12 who died during the first two weeks, were autopsied by Major Yamashina (AIP Key nos. 1-12). The second series were performed from 29 August to 7 September by

members of the staff of Tokyo Imperial University (AIP Key Nos. 21-46). Patients who died late in September or early in October were necropsied by members of the First Tokyo Hospital, especially Major Ohashi (AIP Key Nos. 13-20). The results of these investigations were carefully summarized in the Japanese report. The original material was reviewed by the Joint Commission and the results appear in Section 8, together with material from other sources.

The Japanese report contains a detailed statistical analysis of certain symptoms, especially epilation, in relation to time of onset, distance, sex, and other factors.

A casualty study of groups of school children, suggested by the Joint Commission, was carried out by the Army Medical School and is reported by them. The data analyzed according to exposure groups, appears in Section 10H of the Joint Commission Report.

Other valuable investigations were made by the Japanese medical officers, including a study of groups of soldiers who came to the central district shortly after the explosion and who stayed there for several days. None of these was found to be suffering from severe radiation sickness although the sedimentation rate was elevated. None of the leukocyte counts was below 5,000.

In a civilian group from the village of Ishiuchi, however, who worked at Hiroshima shortly after the bombing, there were a few patients with leukopenia when tested at the end of September 1945. About 1/3 of them had been caught in the rain which fell a few hours after the explosion. Since the village was some 8 km. downwind from Hiroshima, split products

could conceivably have fallen in this area. None of the patients was severely ill. The factors involved are complex and consequently difficult to analyze.

Near the village of Furue, there was found a zone where the radioactivity was several times that of the background for the Hiroshima area. Here, there had been a colored shower. Fission products were proved to exist in low concentration in this area. Six villagers were found who had not been in Hiroshima. None of these was found to have leukopenia when tested on 4 October 1945. Two had counts between 11 and 12 thousand. Unfortunately no previous nor subsequent leukocyte counts are available for the group.

Physical data obtained by members of the Institute for Physical and Chemical Research between 15 and 17 August and again at the beginning of September are presented. Since the work of the physicists Yamasaki, Sugimoto, Tamaki, and Kimura and of the biophysicist Murati is described in detail in the Appendix of Section 2, no further comment will be made here except to present the dosage data prepared by the Japanese. (Figure 3).

The physicists calculated the number of thermal neutrons on the basis of radioactivity of phosphorus in bone to be of the order 10^{25}, and of fast neutrons, on the basis of radioactivity of sulphur, to be approximately 10^{23}. From these estimates, the gamma ray dosage at various distances produced by capture of thermal neutrons in nitrogen was calculated, as was the fast neutron dosage in r units. This last dosage was multiplied by a factor of 5 to give the maximal biological equivalent as compared with gamma ray r dosage. The result plotted as if the total r dosage were from gamma rays

are shown in figure 3. The writers state that the values for the total r dosage as shown here are higher than indicated by biological effects since the zone where epilation was observed did not in their experience extend beyond 1300 meters. This would correspond to a dosage of approximately 600 r of gamma rays at energy of 2 million electron volts. The calculated roentgen dosage at this point, however, is approximately twice as much.

Among other observations, were those made of photographic materials which had been obtained from various hospitals and shops. They included X-ray and other negatives and printing papers. Fogging was detected in such materials as far as 3 km from the center.

2. The Research Commission of the Kyoto Imperial University: "Preliminary Report of the Disaster in Hiroshima City Caused by the Atomic Bomb."

Kyoto Imperial University together with Kanazawa Medical School sent this commission into the Hiroshima Area on 4 September. They established themselves in two groups, one at Ono Hospital where 76 inpatients and 124 outpatients were studied and the other at Usida in the reservoir area of northeast Hiroshima where many patients had taken refuge. Six hundred and forty-five outpatients were seen there. The work of this commission was tragically interrupted when, during the great typhoon of 17 September 1945, shortly after 10 PM, a landslide crashed through the central section of the hospital, carrying into the sea 10 of the outstanding investigators including Professors Sugiyama and Mashita, together with most of the patients, records and equipment. The clinic at Usida also was damaged. According to their report "with much regret we, therefore, had to stop our work at Hiroshima and return with the ashes of our friends."

The report nevertheless presents much of value. There were recorded the findings of 3 necropsies performed during the first week after the bombing. These were said to have been performed at Ninoshima by Dr. Sugiyama but were also reported under the name of Major Yamashina of the Tokyo First Army Hospital. Slides and protocols were obtained from both sources and appear as Key Numbers 2, 3, and 4 in the Army Institute of Pathology series. Focal pulmonary emphysema found in these patients was interpreted as associated with blasts. Summaries of the protocols of 13 necropsies performed as Usida and 8 at Ono also appear together with a series of 26 photomicrographs.

There are many tables of clinical symptoms and laboratory data classified by distance and time of observation. A table of normal values for white and red blood cell levels in persons in the Hiroshima Prefecture is supplied. The date on which the counts were made and the exact location of the subjects is not stated (table 1).

The Takata-Ara reaction was positive in 14 of 21 patients, more frequently when the leukocyte count was below 2000. The reaction was negative, however, in 3 severe and 4 mild cases of radiation effect.

Blood bilirubin estimated in 17 severe and 4 mild cases was found to be elevated only in one instance.

Vitamin C levels were reduced in practically all subjects.

The electrocardiograms were studied in 50 patients varying from 18 to 45 years of age. The Q-T interval was prolonged in 9 of these and the T wave had a diminished amplitude in 3. These findings were thought to be associated with "anemia and asthenia." In one mild case there was an unexplained bundle branch block and in another the findings suggested an

TABLE 1*

Normal Values of WBC, RBC, and Hgb in Hiroshima Prefecture

	Number of Observations	WBC	RBC	Hgb (%)	Color Index
Maximum	42	13520	5.44	108	1.34
Minimum	(total)	4550	3.41	79	0.76
<u>Age 5 - 74 years</u>					
Male	23	7320	4.54	95	1.05
Female	19	7528	4.35	94	1.09
Average	42	7424	4.95	94.5	1.07
<u>Age 15 - 55 years</u>					
Average	33	7226	4.48	97	1.08

* From Setsuda, Fukase and Wakisaka

infarct of the myocardium.

3. Drs. M. Fujii, K. Shirai, H. Sawazaki, Y. Ogasawara, H. Tanabe: "The Effects of Atomic Bomb on the Human Beings at Hiroshima". A Report from the Hiroshima Sanatorium at Saijyo.

This detailed report concerns 77 patients with "radiation sickness" and 32 patients who had burns of varying degrees of severity. It is illustrated with 58 tables, 5 figures and 2 maps. It is an attempt at statistical analysis and correlation of symptoms based upon this rather scanty material. Studies were made of fever in relation to the symptoms. Among the conclusions are:

1. That the fever appears earlier, the more severe the disease.
2. That epilation usually appears earlier than the fever.
3. Pharyngeal pain and tonsillitis begin at the same time as the fever, or later.
4. Gingivitis and petechiae usually become manifest later than the onset of fever.
5. In relation to defervescence. Pharyngitis ceases before, petechiae before or during, and gingivitis usually after the end of the febrile period.

Correlation is also made, in these relatively late cases, of symptoms with leukocyte counts. It is concluded that epilation, fever, pharyngitis, gingivitis and petechiae occur before the leukocyte count reaches its minimum.

It burned patients, the minor burns were usually associated with leukocytosis but leukopenia appeared more frequently among patients with extensive burns. The latter were found to have been closer to the center, which probably accounts for this difference.

Twenty-two electrocardiographic examinations were made. The changes were minor except in one case where ventricular extrasystoles were found together with other changes interpreted as indicative of "myocardial lesions". (One note among the observations of interest was that the Rumpel-Leed test was positive only in a few instances even in patients with severe symptoms of radiation effect. Resistance of blood capillaries tested by Borbely's method also was found to be normal except in one case.

4. J. Kuno. Lieut. Comdr. Japanese Navy: "Report on Patients Injured by the Explosion of the Atomic Bomb in Hiroshima". Iwakuni Naval Hospital.

This paper concerns 51 patients who had been transported to Iwakuni by ambulance on 6 August and 2 patients brought by boat from Nagasaki following the bombing on 9 August in that city. The following are the observations of note:

TYPE OF INJURY

Burns alone	34
Burns and Mechanical injury	47
Simple Traumatic Injury	19

It was stated that almost all patients had burns of eyelids and simple conjunctivitis which disappeared in between 3 and 7 days. Other observations are of a non-specific nature and no particulars concerning dates are supplied.

5. Hematological Study of the Atomic Bomb Disease. Nakao, K., Kobayashi, G., Kato, S., Yano, Y., and Komiya, N. Imperial University of Tokyo, Medical Clinic (Dr. K. Sassa).

Nakao and his co-workers summarized the results of an examination of a total of 1681 patients. Precise clinical and hematological records were

made of 107 of these. Included in the report are counts on specimens of bone marrow obtained in 91 punctures of some 75 patients. All of these specimens were made available to the Joint Commission and have been reviewed together with the clinical histories of the patients.

The work was in 2 main phases. Between 3 and 11 September, observations were made at the Ujina Hospital as part of the cooperative effort of the Tokyo Imperial University and the Military Medical authorities at that establishment. The second phase was after 12 October when the group from Tokyo Imperial University was functioning with the Joint Commission. In addition, material was made available by the Iwakuni and Saijyo Hospitals. These patients had had hematological studies during the first week after admission. Clinically they exhibited fever, stomatitis, and pharyngitis within the first week. There was also a rapid development of anemia and some nucleated erythrocytes appeared in the peripheral blood. Further evidence of rapid destruction of the marrow was the severe leukopenia which occurred within the first seven days. Giant neutrophiles were present. The most rapid fall occurred in the lymphocytic series. In a few instances the platelets also fell moderately but the maximum reduction was not until the 3rd to 4th week. During the period of regeneration in later cases, Nakao noted one patient in whom the platelets rose to very high levels temporarily followed by a fall to slightly greater than normal figures. In the material from the regenerating marrows there were also large cells which he termed megaloblastoid. Eosinophiles were prominent in the peripheral blood and bone marrow at this time. The lymphocytes came back slowly and in some cases were not quite up to normal at the 8th week.

One conclusion was that the remarkable difference between this and other types of aplastic anemia was the greater hypoplasia of the marrow, which however retained a capacity for regeneration.

6. Patho-Anatomical Studies of 34 Atomic Bomb Cases at the Cities of Hiroshima and Nagasaki. (The First Report). M. Miyake, Pathological Institute, Tokyo Imperial University.

This, the first report, is a description and analysis of 28 cases from Hiroshima, 2 of which were necropsied at Tokyo Imperial University, and of 6 patients autopsied at Nagasaki. Material from all but one of these is now in the U. S. Army Institute of Pathology, and the results of the American review of the material is part of the Joint Commission's report.

Miyake's review is divided into 7 parts. The preface considers the injurious factors in the bombing and the determinants of their effect upon the patient, such as position, shielding, etc. The section on methods outlines the 10 clinical and 10 "patho-anatomical" headings under which the findings are subsequently detailed.

The body of the report is a detailed and systematic description of each of the cases. The translated protocols are in the AIP files. Then follows a general review of the observations at necropsy and a reclassification of what, in the opinion of the writer, are the direct and indirect effects. Forty-eight photomicrographs illustrate the cases.

7. Kentaro Shimizu (Tokyo Imperial University) "Influence of the Atomic Bomb upon Spermatogenesis."

This report presents data concerning 8 patients who had not received mechanical injury. Seven of these patients were from Hiroshima and one from

Nagasaki. The findings in one man who had been at Hiroshima 3 km. from the center were normal. The counts in other individuals generally showed a reduction of motility and an excess of abnormal forms, particularly if the second or later ejaculates were examined. Reduction in numbers occurred in those who had had severe leukopenia.

The writer states that the normal volume in Japanese is 2 to 5 grams, the normal number above 48,400, and the percentage of abnormal forms less than 25%.

8. Eiji Hamamoto: "Active SH Base of Serum Protein of Patients Injured by the Atomic Bomb". Okayama Medical College.

Nineteen convalescents at Okayama Military Hospital were tested on 2 November 1945. In all of these the active SH base appeared to be reduced but the total proteins were elevated. This suggested to the writer a change in the quality of serum protein.

9. Bunsaku Arakatsu: "Field Observations at Hiroshima on the Radio-Activity Induced by the Atomic Bomb." Kyoto Imperial University.

Geiger counts on the West Parade Ground (very close to the point above which the bomb exploded) showed 70 to 80 counts per minute but on the East Drill Field (2.5 Km) there was no appreciable increase above background. There was evidence also of activity in the Koi district. Materials gathered near the center showed high induced activities, particularly the horseshoe magnet of an integrating watt-hour meter. Evidence indicated that neutrons of a wide range of energies had bombarded the central district.

10. Tsunesaburo Asada: "Report on the Atomic Bomb Thrown on Hiroshima". Osaka Imperial University.

This is a general discussion of physical observations made on

10 and 11 August 1945. It presents the usual observation concerning "shadow" effects, etc. There are also reports of counts made with the Geiger-Mueller counter, which showed maximal values at the Gokoku Shrine and near the Koi Station in the western district of Hiroshima. These findings are compatible with those of others.

11. Itoh, J., Ozaki, S., Nagato, M.: "Researches on the Radio-Activity at Hiroshima". Osaka Imperial University.

This is a detailed report of the general observations presented by Dr. Asada, which had been made on 10 and 11 August. The radio-activity of soil gathered at several places in the city, was found greatest near the Gokuku Shrine at the entrance of the West Parade Ground and the Koi Bridge. A map of the places where the specimens were obtained is also presented. The activities there were found slightly, if at all, greater than normal. The bones of a man who had been 2 km from the center were tested and found negative. Chemical separation of the soil obtained at the Koi Bridge was attempted and the activity was found to be associated with radioactive strontium and other split products.

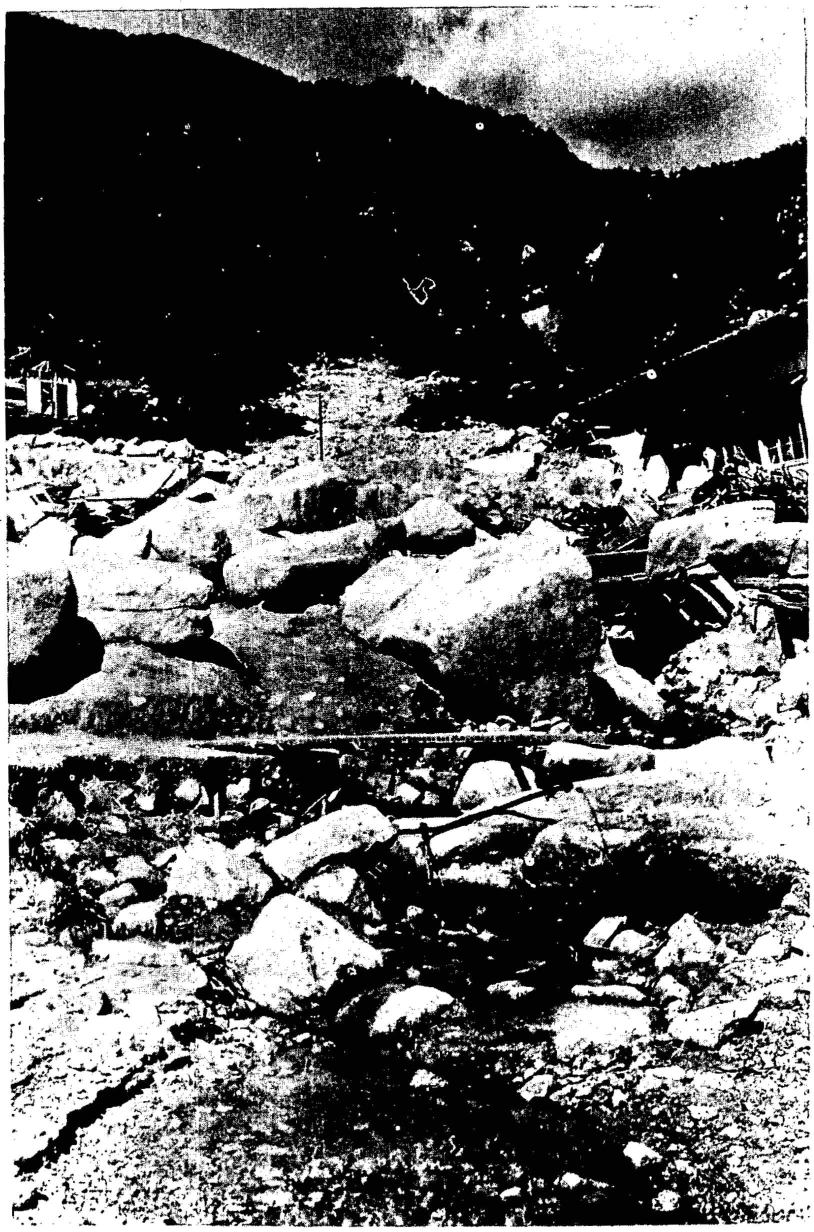
Thorium or some other rare earth element also was found.

Fig. 1--(4H). The Ujina Hospital (converted Daiwa Rayon Mill) at Hiroshima (4300 m.). This was the headquarters of the Hiroshima section of the Joint Commission. The wards and living quarters are arranged in cantonment fashion behind and to the left of camouflaged factory buildings. (Photo File #HG 131; (K).)

Fig. 1A--(4H). Entrance to Ujina Hospital. Sign reads "Hiroshima Army Hospital, Ujina Branch." (Photo File #HH 168.)

Fig. 1B--(4H). A group from the laboratory of the Joint Commission at the Ujina Hospital, Hiroshima. Four of the nurses who assisted in preparation of the glassware are shown. The physicians are, from left to right, Dr. Kato, Dr. Kajitani (at rear), Dr. Nakao (the hematologist of Tokyo Imperial University Hospital, Professor Sassa's Clinic), Capt. J. Philip Loge, Dr. Tsukada, and Dr. Okoshi. (Photo File #HH 167; (K).)

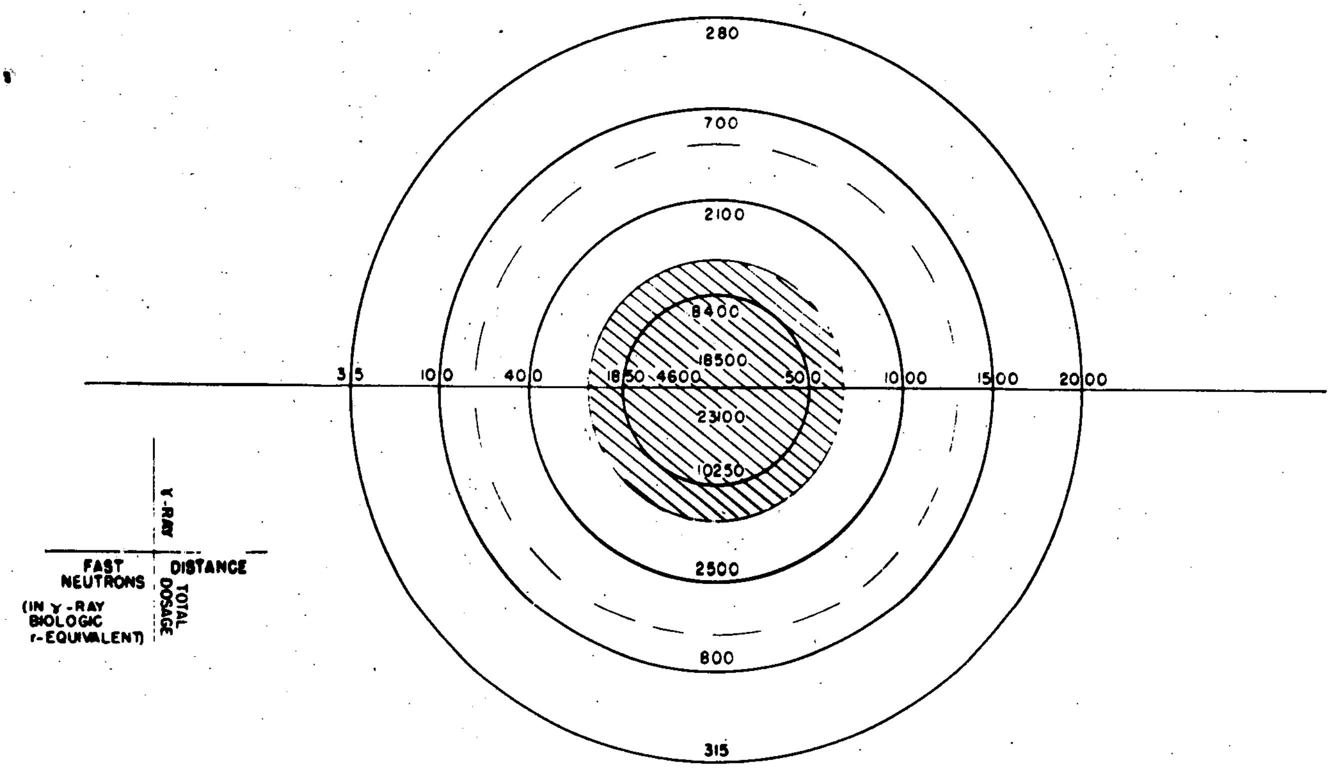
Fig. 2--(4H). Clinic in session at a temporary building at the Hiroshima Central Railroad Station. Senior students and recent medical graduates are interviewing and examining the survivors. A microscopic examination is being performed. Seated at rear on right is Dr. Hatano, the physician in charge of the examiners, and Major M. L. Kramer of the Joint Commission. Dr. Terry, of the USSBS, is with Major Kramer. (Photo File #HH 258.)



Appendix Fig. 1--(4H). Ono Army Hospital, Mariushi, Ono Village, Sehikugun, Hiroshima Prefecture. Professor Mashita of the Kyoto Imperial University research group who was investigating the atomic bomb casualties and ten other investigators were killed by landslide and flood on 17 September, 2210 hours. Professor Sugiyama, the pathologist, also was lost. (Photo File #HH 229.)

Appendix Fig. 2--(4H). Ono Army Hospital after the typhoon of 17 September 1945. (Photo File #HH 231.)

DISTRIBUTION OF r DOSAGE



IN SHADED AREA BONE DISPLAYED RADIOACTIVITY
CORRESPONDING TO MORE THAN 1.3×10^4 β RAY PER MINUTE PER GRAM

BROKEN CIRCLE CORRESPONDS TO ZONE
WHERE EPILATION WAS OBSERVED IN PATIENT

Appendix Fig. 3--(4H). (Photo File #HP 161.)

Section 4N

MATERIALS AND METHODS

Prepared by George V. LeRoy, Lt. Col., MC

The materials which formed the basis of this report can be divided conveniently into three categories: (1) case records, autopsy tissues and protocols, and reports of scientific investigations prepared by Japanese workers; (2) clinical data collected in collaboration with Japanese physicians and medical students; (3) clinical observations and laboratory studies carried out in Japan; at the Army Institute of Pathology, and at the Naval Medical Research Institute by members of the Commission.

The Japanese Records - The Naval Hospitals.

The majority of the casualties who received hospital care were taken to Japanese naval hospitals in the vicinity of Nagasaki. These hospitals were located at Omura, Ishahaye, Kawatana, Ureshino, and the quarantine station at Sasebo. The quality of medical care in these institutions was variable, and only in the first two were suitable records maintained. As might be expected during the first week after the bombing, all the records were extremely brief and seldom contained more than a short description of the wounds. However, after the appearance among the casualties of the syndrome due to exposure to gamma radiation, the quality of the records improved. This was true in particular of Omura Naval Hospital. These military hospital records are the only contemporary source of data on the relative proportions of the several types of injury. It is not proper, however, to accept their figures without qualification, because the patients who were admitted were a selected group. The selection was due primarily to the fact that virtually all the evacuation was by rail from the Urakami station. Therefore, only the patients who could walk or were carried to this station were reported in the casualty list. Actually, this is not too serious an objection to the data, since the Urakami

station was close to GZ. Of all these hospitals, the Omura Naval Hospital provided the best medical care. (figure 1, 2, 3). The patients were retained there from 9 August until December, when their condition warranted it. The fact that this group received continuous care in one institution makes its records quite valuable. With the cessation of hostilities and the occupation of Japan, the other Naval Hospitals discharged their civilian patients as rapidly as possible and frequently long before the patient was fit to be moved. At the same time, the morale of the Japanese Naval medical officers deteriorated so that after a few weeks the care of the patients can only be described as perfunctory. The commanding officer of the Omura Naval Hospital, Surgeon Rear Admiral YASUYAMA, however, was a remarkable man who was able to maintain high standards of medical care in spite of these conditions. He refused to discharge the victims of the atomic bombing and incurred considerable official displeasure by his liberal attitudes in general.

Shinkozen Medical Aid Hospital.

In the City of Nagasaki, aid stations were established in many of the public buildings (See table 3, Page 19; Section 3N). These were operated during the first few weeks after the bombing by volunteers.
No records of any sort appear to have been kept by the first aid workers. The Shinkozen Medical Aid Hospital was the exception. It was a modern, reinforced concrete Public School building which was moderately damaged by the blast. The School functioned as a hospital and a dispensary from 9 August, when the first victims sought refuge there, until 30 October, when the remaining 80 patients were evacuated to Omura Naval Hospital.

The staff of the hospital changed frequently. On 9 August, members of the Medical Aid groups in the city began treating the casualties. By 12 August,

the number of cases was so large that Naval Medical detachments from Sasebo and Hariojima took sole charge. After the surrender of Japan, these were withdrawn and local physicians whose clinics and offices had been destroyed provided the medical care under the supervision of a Director appointed by the Mayor. The various medical aid groups from out of town helped out, as did the remnants of the faculty of the Nagasaki Medical College. After 1 October, American Medical Officers of the Joint Commission arrived and used the hospital as a base of operations for their investigation. In the middle of October, the faculty of Nagasaki Medical College took charge of the place and provided an administration, in addition to using it as a temporary home for the College.

An estimate of the number of patients cared for during its entire operation is:

Outpatients..............	9,000
Hospitalized patients....	800
Deaths..................	350

Records were not kept for all the patients, but such as are available are valuable, for they represent a true cross-section of the sort of casualty that was cared for.

Other Hospitals.

Casualties from Nagasaki sought hospitalization eventually in many of the medical centers of Kyushu and Honshu. The hospital of the Kyushu Imperial University of Fukuoka cared for the largest number of these, and excellent medical records were kept. Transcripts of the majority of these clinical reports and autopsy protocols were given to the Commission by members of the faculty. A small number of patients were hospitalized in Kumamoto, Ube, Kyoto, Osaka, Okayama, and Tokyo. It was possible to obtain abstracts of

these clinical records. In many instances, this clinical data was sufficiently detailed to permit the completion of the Joint Commission's questionnaire for each case. The records of about 600 patients were obtained in this way. In general, the data obtained from medical school hospitals is complete and gives the impression of having been recorded accurately.

The Medical Research Groups.

Teams composed of physicians and medical students went to Nagasaki at various times after the bombing. Such groups were of two distinctly different types. One type was the group from Kyushu Imperial University, who arrived in the city 29 August. Their primary mission was to study the degree of residual radioactivity in the area, as well as the characteristics of the effects of gamma radiation. In addition to this, they worked diligently with the local doctors providing medical care in the dispensaries and in particular at the Shinkozen Medical Aid Hospital and the Omura Naval Hospital. The personnel changed constantly in accordance with a rotation policy, so that most of the younger faculty members, and many of the senior students were afforded an opportunity to study the victims of the atomic bomb. From the time of their arrival until December, there were always at least six members of the faculty with a variable number of students working with the casualties. The members of this group were exceptionally diligent, and their records are some of the best that are available. They devised and used a questionnaire and initiated a number of studies of special problems which will be referred to later.

The other type of medical visitor was represented by a group from the Kumamoto Medical College. These workers arrived on 4 September, and departed on 8 September. They performed approximately 20 autopsies, primarily on patients for whom no clinical data was available, or recorded. They made brief

clinical notes and single blood examinations on approximately 200 patients, and then returned with their materials to their homes to prepare a report. A number of such groups appeared. In general, their records were of little value. The physicians were more concerned with the novelty of the illness than with providing continuing care to the victims.

At one time or another a small number of physicists, engineers, and agriculturists came to Nagasaki. They investigated various situations related to their specialties, and after a few days, they, too, returned to their universities to correlate their data and to write their reports.

Other Material.

In addition to the clinical records, it was possible to obtain from the Japanese doctors a considerable amount of pathologic material. Wherever possible, wet tissue, gross specimens and autopsy protocols were requested. Specimens and data from 50 autopsies were finally obtained. Approximately 300 blood films and sternal marrow biopsy preparations, with pertinent clinical data, were also collected. As rapidly as the medical research teams finished their studies and prepared their reports, copies were submitted to the Joint Commission. In this manner, a considerable quantity of material is available for study and analysis. Much of this work was done by the Japanese in the first month and a half after the bombing, that is, prior to the arrival of the Joint Commission. It is invaluable, for there are no other records or pathological specimens from that period.

Comment.

It is difficult to generalize on the quality of the scientific and clinical reports. It is probably reasonable not to make the attempt. A resume of the reports included at the end of this section and all the titles, are

listed in Appendix 4 N . Throughout all of the early Japanese medical studies there was one common trend. The point of view of the workers was "research" into the nature of "the atom bomb disease". There appeared to be less interest in treatment, and it is surprising when the records are reviewed to observe the scarcity of experiments in therapeutics. In all except a few of the large hospitals where the victims of the bombings were cared for, a similar attitude prevailed. It was difficult to determine the reason for this lack of interest in therapy. There was no evidence that any novel type of treatment was adopted, or that major changes in established routines were made. The conventional remedies were administered in the customary amounts, and the failure of the patients to respond appeared to have little influence on the curiosity of the attending physicians.

COLLABORATION OF AMERICAN AND JAPANESE DOCTORS.

In the collection of material in Nagasaki, two types of collaboration were taken advantage of. One was planned in advance and is represented by the activities of the medical group from the Tokyo Imperial University; the other was accidental and is represented by the activity of workers from the Kyushu Imperial University and the Nagasaki Medical College. The members of the Faculty of Medicine of the Tokyo Imperial University (see introduction) were recruited by Professor Masao A. TSUZUKI and were subsidized by the Japanese equivalent of the National Research Council. Their association with American military personnel was legitimized by a General Order. This order designated a Joint Commission which was composed of representatives from the Office of The Chief Surgeon, GHQ, AFPAC, members of a party from the Manhattan District, Corps of Engineers, and the Japanese physicians. The latter were attached to the Commission for the specific purpose of assisting in the collection of clinical

data by the questionnaire method. In addition to this, each Japanese associate was encouraged to pursue research in his special field of interest, under the direction of the American physicians. The arrangement was successful and it would have been impossible to obtain the same amount of material without the active assistance of these physicians.

A second group of Japanese under the direction of Dr. Motosabura MASUYAMA, a statistician from the Tokyo Imperial University, actively assisted Captain Marvin E. Habel, FA, in collecting and analyzing the data on population and casualties which formed the basis of Section 10 N of this report.

When the Joint Commission arrived in Nagasaki 30 September, they encountered two groups of Japanese who were working with the casualties. One was a party from the Kyushu Imperial University, most of whom were members of the Sawada Clinic of the Faculty of Medicine. These men were under the immediate supervision of Professor SAWADA's associate Dr. K. KAIDA. The other group was the faculty and the student body of the Nagasaki Medical College under the leadership of Acting Dean K. KOYANO. Wherever possible, the activities of these groups were coordinated with those of the Joint Commission to provide additional personnel for the task. Most of the faculty members of each group spoke English and the majority of the students had at least a satisfactory reading knowledge of it. In addition to all these personnel, a number of interpreters, Red Cross nurses, and other assistants were provided from time to time by the prefectural and municipal authorities. These workers who were fortuitously affiliated with the Joint Commission were extremely helpful because of their intimate knowledge of local conditions and customs, and because of their familiarity with the medical effects of the atomic bomb.

Type of Material Studied.

The joint studies which were conducted in Nagasaki can be divided into

four groups: (a) Clinical observations on patients in hospitals and dispensaries; (b) Laboratory studies on the same type of patients; (c) Questionnaire studies of survivors; (d) Special investigations.

a. The clinical material which was available consisted of patients in the Omura Naval Hospital and in the Shinkozen Medical Aid Hospital. During the period of observation, about 350 patients were observed in each institution. Because of the primitive facilities at Shinkozen, the turnover of patients was rapid and the opportunity for detailed study was limited. For this reason the workup of these patients consisted usually of the completion of a questionnaire, a brief physical examination, and one or two routine blood examinations. In the Omura Naval Hospital, conditions were more satisfactory and patients were willing to remain under observation and care for prolonged periods. The case studies in this hospital were accordingly more complete and the general plan contemplated frequent examinations throughout the entire time that the Commission was on hand. The workup there consisted of the completion of a questionnaire, a fairly detailed history and physical examination, frequent progress notes, and laboratory examinations repeated at intervals of approximately one week, during the patient's stay in the hospital.

The Shinkozen Medical Aid Hospital continued to function as a dispensary to which casualties came to have their wounds dressed, and for such medical care as they required. The outpatient service was operated by the faculty and students of the Nagasaki Medical College. This dispensary provided a source of material for the Joint Commission. A questionnaire was completed for each patient applying for care, as well as any members of his family or friends who accompanied them. A minimal physical examination was conducted

and laboratory studies were performed on a selected portion.

The majority of the casualties whose wounds were minor had recovered by the time the Commission arrived. It was necessary, therefore, to go through the city seeking out as many of these people as possible. The questionnaire was completed on each, and wherever possible, uninjured survivors who had been in the same general vicinity were also interrogated, and questionnaires were filled out for them. This type of study was carried out in detail for groups of subjects who had been in the same building at the time of the bombing. The job of locating these subjects was done primarily by the Nagasaki medical students under the direction of the physicians of the Tokyo Imperial University. In the course of the seven weeks that the Joint commission spent in Nagasaki, questionnaires were completed on approximately 6,600 individuals.

The collaboration of the Japanese members of all the groups was indispensable in this task. The general quality of their work was satisfactory, and a survey of 1200 sample questionnaires by one of the American medical officers (Major Herman Tarnower, M.C.) and a reliable interpreter revealed that fewer than ten percent of the records were so erroneous as to be worthless. The Japanese physicians in charge of the work became quite enthusiastic, and the original forms written in Japanese have been retained by them for independent analysis. Throughout this phase of the study, close association was maintained between the American and Japanese workers. Frequent conferences were held with respect to the progress of the work; and in many informal meetings all phases of the study were reviewed and discussed. In general, the medical officers acquired a considerable degree of confidence in the veracity and ability of the Japanese physicians and medical students who

assisted them.

OBSERVATIONS OF AMERICAN DOCTORS

The materials contributed to this study by the American members of the Joint Commission can be classed in three groups: Clinical, laboratory and analytic. Because of the large scale of the investigation, the small size of the staff, the paucity of scientific equipment and the difficulties inherent in a situation where the subjects of investigation speak another language and are the vanquished, no one was able to study any subject so thoroughly as he had hoped. The necessity of supervising the Japanese work, and checking many of their observations consumed much time. The difficulty of obtaining a precise clinical history from a Japanese patient through the medium of an interpreter, can only be appreciated by one who has tried it. In addition to these handicaps, there was no provision in the plan of the Commission for administrative officers, so that many of the details of procurement of supplies, housekeeping, transportation and communication, had to be executed by the doctors, in addition to their other duties. In spite of this, they accomplished the following in Japan:

a. The majority of the physical examinations of hospitalized patients.

b. The majority of ophthalmoscopic examinations of all patients.

c. Supervision of the enlisted men and the Japanese students and nurses in the conduct of the laboratory.

d. Approximately one-fourth of all the white blood cell differential counts.

e. All the examinations of marrow obtained by sternal biopsy.

f. The 22 postmortem examinations.

g. Checking the details of location, etc., on the majority of the questionnaires.

h. All the measurements of residual radiactivity, and the collection of pertinent samples.

i. The investigation, through interpreters, of the records of population and casualties.

After the materials referred to were collected in Japan, some of the members of the Commission returned to the United States. All the clinical records, questionnaires, specimens, and data were sent to the Army Institute of Pathology, and to the Naval Medical Research Institute. In these institutions a detailed review of all the material, and an analysis of the data was conducted.

The Questionnaire.

The nature of the questionnaire, and the particular features peculiar to its use in Nagasaki is discussed in detail in Section 9. .

The Casualty Study.

The type of investigation conducted by Capt. Marvin E. HABEL, FA, is discussed in detail in Section 10 H and 10 N.

The Statistical Study

The statistical code used in the transfer of data from the questionnaires to the IBM cards was substantially the same for each city. A detailed discussion of this subject will be found in Section 9. of the Report. To simplify the process of analysis, the location of subjects in Nagasaki, which had been recorded in a system of rectangular coordinates, was coded in terms of polar coordinates. The dimensions of the polar coordinates were the same for each city so that comparisons could be made easily.

The Laboratory Studies.

Clinical laboratory facilities were not very adequate. The military situation was such that the medical supply depots had little equipment to spare. To perform the tests described below, it was necessary to obtain

material in small amounts from a number of sources as the Okinawa Base Command, and the Tokyo Imperial University. The Commanding Officer of the Omura Naval Hospital assigned a fine group of laboratory rooms (figure 4) to the Joint Commission. There was running water, ovens, balances, some chemicals and electrical outlets, but little else. The other field laboratory at the Shinkozen Medical Aid Hospital (figure 5) was destitute of everything but electricity. The Medical section of the Naval Technical Mission to Japan and the U.S.S. Wichita provided microscopes and additional laboratory apparatus. With these modest facilities it was not possible to perform many types of examinations. In addition to this, personnel were few, and the scope of the investigation was such that there was little time for more extensive studies.

The types of laboratory examinations which were made in each of the field laboratories, and the approximate numbers of such tests are presented in table 1. The tabulation includes the work done by American and Japanese doctors.

TABLE 1

Type of Examination	Omura Naval Hospital	Shinkozen Hospital	Total
1. Autopsy	16	6	22
2. Routine Blood Counts on Patients	1100	900	2000
3. Routine Blood Counts on "Normal controls"	100	50	150
4. Reticulocyte Counts	160	90	250
5. Price-Jones Curves	-	60	60
6. Blood Platelet Counts	60	40	100
7. Determination of Bleeding and Clotting time	30	20	50

Table 1-continued:

Type of Examination	Omura Naval Hospital	Shinkozen Hospital	Total
8. Prothrombin Time (Howell's Method)	30	-	30
9. Biopsy of Sternal Marrow	74	54	128
Urinalysis			
10. Urobilinogen Test	230	-	230
11. Albumin	230	-	230
12. Microscopic	40	-	40
Gastro-intestinal Examination			
13. Histamine Test for secretion of free HCl	45	-	45
14. Gastroscopic examinations	20	-	20
15. Barium meal	11	-	11
16. Estimation of Whole Blood chlorides - Patients	174	-	174
17. - Controls	11	-	11
Takata-Ara Reaction			
18. 349 Patients	598	-	598
19. 62 Controls	62	-	62

A description of the methods used on each type of determination follows:

1. The autopsy was performed as quickly as possible after death. During the period of the study the members of the Joint Commission failed to perform autopsies on only two of the patients who died. It is interesting to remark that verbal permission was obtained from the family of the deceased in every case and that only exceptionally was it granted with hesitation. The examination was complete in every respect. The results have been recorded in

protocols which conform to the standards of the U. S. Army Medical Department. (Reference: "Form for Autopsy Protocol" distributed by Army Institute of Pathology, undated.)

2. The majority of the routine blood examinations were performed on oxalated blood. The values for hemoglobin-hematocrit and plasma protein content were obtained by the Copper Sulphate Method. (Reference: Phillips, R. A., and others; Bulletin U. S. Army Medical Dept. #71 pp. 66-83, Dec., 1943.) The stock solutions of Cu SO_4 were made from Japanese reagents, and a sample of each was sent to the 18th Medical General Laboratory for verification of the specific gravity. The results of this examination were as follows:

	Theoretical	Actual (pycnometer method)
a -	1.100	1.1043
b -	1.100	1.1041
c -	1.100	1.1028
d -	1.100	1.1012
e -	1.065	1.0653

Approximately 85% of the determinations were made with stocks d and e. In calculating the plasma protein concentration from the nomogram, a correction of plus 0.64 Gm was applied.* When venous blood was not obtainable, capillary blood was used. U. S. Navy-grade red counting pipettes were used. The hemoglobin concentration was determined either in the Hayden-Hauser apparatus or in the Japanese Sahli Hemoglobinometer. Each of these instruments is calibrated so that 14.5 Gm of the hemoglobin equals 100%. Leukocyte

*This correction factor was established at the 18th Medical General Laboratory. The reference is a Circular Letter, not available at this time.

counts were done in the usual manner. For all cell counts American hemocytometers were used. None of this equipment was certified by the Bureau of Standards, but it was all of excellent quality.

Blood films for differential counts were made from freshly drawn (never oxalated) blood, either on slides or cover slips. Wright's stain was used routinely.

3. Reticulocytes were counted in blood films on slides prepared with an alcoholic solution of Brilliant Cresyl Blue, and stained with Wright's stain.

4. Price-Jones' curves were estimated for erythrocytes on cover slip preparations. The measurements and calculations were all made by Major Samuel BERG, MC, working at the Army Institute of Pathology. The statistical treatment of this data was carried out by Mr. M. Geisler, a member of the staff of the Army Institute of Pathology.

5. Blood platelets were counted by Fonio's method.

6. Bleeding time was estimated by Duke's method. Clotting time was estimated by the capillary tube method.

7. Prothrombin time was determined by Howell's method and was really the clotting time of recalcified plasma.

8. Biopsy of sternal marrow was performed by inserting a large gauge needle directly into the manubrium sterni, after producing local anesthesia with procaine in 1% solution. A number of types of needle were used: but the most suitable was the one issued by the U. S. Army Air Force for the in-flight administration of plasma intrasternally to injured crewmen. The amount of marrow that was aspirated was small, usually less than 0.5 cc. Counts of nucleated cells were not made routinely. The smears were stained with Wright's or May Grünwald stain, and counterstained with Giemsa. The number of cells counted in the differential count varied from 200-500. The

nomenclature of the marrow cells has been discussed in Section 7.

9. Urobilinogen excretion in the urine was estimated rather crudely. The Ehrlich's diazo reaction was performed qualitatively, and the color, if any, which developed was compared with a series of samples. These varied from the faintest pink to deep pink, and were labelled arbitrarily one plus to three plus.

10. Albumin excretion in the urine was determined by the sulphosalicylic acid method. The Japanese standards that were used were of egg albumin, and were graded one plus (approximately 0.1%), to four plus (approximately 1.5%). If albuminuria of any grade was detected, the urine sediment was examined microscopically.

11. The histamine test was performed on fasting subjects. After aspiration of the residual gastric contents, 0.5 mg. of histamine acid phosphate was injected subcutaneously. The gastric secretions were again aspirated 30 and 60 minutes later. The material was titrated with N/10 N_a OH, using Töpfer's reagent for the indicator.

12. Gastroscopic examinations were performed by Dr. K. KISHIMOTO of the Tokyo Imperial University. A Schindler gastroscope was used, and the procedure, and the terminology used to describe the findings were those of Prof. Schindler.

13. Fluorscopic examinations after ingestion of a barium meal were also performed by Dr. KISHIMOTO in a conventional manner.

14. Whole blood chlorides were estimated by the micro method of Koranyi and Rusznyak. (References: Biochem. Ztschr. 110: 60; 114: 23; 1921.) The normal value for this method in control subjects was: 450 - 500 mg %

The Takata-Ara reaction was performed in the manner originally described, except that fuchsin was not used. The results were expressed as positive

(more that 2 of 7 dilutions showed precipitate); or negative. Used in this way, the test is very popular with Japanese doctors, and is used in nearly every clinic. (Reference: Talcata-Ara test; Technique was the same as that cited in Tradwohl, R. B. H., Clinical Laboratory Methods & Diagnosis". St. Louis, Mosby, 1943, P 239.)

Appendix 1 (4N)

RESUME OF STUDIES BY JAPANESE DOCTORS IN NAGASAKI

Japanese Reports Edited by Verne R. Mason, Col., MC

The reference numbers for each paper are in parentheses, and coincide with references in the text of the Report.

The reports to be discussed in this section were all prepared by Japanese doctors who had either participated in the care of the casualties caused by the bombing of Nagasaki, or had been members of medical research teams that conducted special investigations. These studies provide the only information that is available on the medical condition of patients between the time of the bombing and the arrival of the American medical officers. The special studies conducted by the Japanese members of the Joint Commission were complementary to the broader study of the American members. The material contained in these papers has been used freely in the preparation of the Report and it is right that the authors should receive proper acknowledgement for their work.

The section is divided into two parts: (A) Reports of work done independently by the Japanese. Most of these studies were made between 28 August, when the first groups from the Kyushu Imperial University arrived in the city, and 30 September when the Joint Commission appeared. (B) Reports of work done by Japanese under the direction of, or in association with, the American members of the Joint Commission.

The reports have been classified into four categories on the basis of their contents: General Clinical, Special Clinical, Physical, Miscellaneous. Since many of them deal with circumstances in the first 4 to 6 weeks after the bombing, they are valuable sources of information. The fact that the studies were made at that time makes it difficult to review the work critically,

because American doctors were not present during most of this period. It has been possible, however, to verify some of the observations. The USS HAVEN, (hospital ship) AH-12, was in Nagasaki Harbor during September 1945, embarking recovered military personnel. Her War Diary (AG Combat Analysis section file 19422, 6-12.009/45) contained notes on the condition of the casualties which are in substantial agreement with many of the contemporary reports. In the portion of this section, devoted to reviewing the studies, the conclusions that are presented are mainly those that differ materially from the ones submitted in the main body of the Report. The basis of such criticism as is offered has been broad. It depends to a large degree on the reviewer's personal knowledge of the intellectual qualities and the capabilities of the Japanese doctors concerned; and to an equal extent on the reasonablness of the work as judged from internal evidence. The reports cited are filed in the Army Institute of Pathology, under the general accession number: 158930.

(A) Reports of work done independently by Japanese doctors:

GENERAL CLINICAL STUDIES

(1) "The clinical investigation of the atomic bomb disease", by the members of the III Medical Clinic (Prof. T. SAWADA, Chief) Kyushu Imperial University.

This is a well written study of approximately 500 cases seen in Nagasaki and at the clinic in Fukuoka. Most patients were observed during the period 31 August to 31 October, and the major investigative effort was devoted to those with the severe type of radiation injury, whose symptoms developed between the 1st and 4th week after the bombing. On an empirical basis the following prognostic guides were offered.

a) The more severe the "main symptoms" (i.e. fever, epilation,

gingivopharyngitis, purpura and leukopenia) the worse the prognosis.

a) In the absence of fever and gingivopharyngitis the prognosis is good whether epilation occurs or not.

c) The prognosis is poor in patients whose sternal marrow is of the "reticular" variety.

The only definite abnormalities of bodily function that this group could ascertain were the disturbance of hematopoiesis generally, and some indefinite hepatic dysfunction. In the group of 40 patients with "severe" radiation injury that were treated in the clinic, the mortality was 10%. Whole blood and crude liver extract were recommended as the most effective therapeutic agents.

(2) "Researches on patients injured by the atomic bomb", by members of the II Medical Clinic, (Prof. G. KUSUMOKI, Chief) Kyushu Imperial University.

This report is based on a study of 155 patients (142 from Nagasaki) in a majority of whom the only injury was due to gamma radiation. The presentation of the data is so devious that it is difficult to determine the outcome of the individual patient. Of the group of 10 hospitalized cases who presented hematologic evidence of severe radiation injury, 3 died. American doctors gave this group some penicillin and 2 febrile patients were treated with good results apparently. There are no protocols for these patients and no notation of the size of the dose, or duration of administration.

(3) "Clinical observations of atomic bomb disease" by members of the I Medical Clinic (Prof. T. MISAO, Chief) Kyushu Imperial University.

The major portion of this report is a careful and complete study of 23 patients treated in the hospital. Nineteen of these were seriously ill, and of this number 4 died. From their study of these patients and 115 other

less severely affected ones, the authors drew several interesting conclusions. One was that persons who remained in the region of the center of the bomb explosion developed a more serious type of radiation injury than was observed in others who left the scene at once. They were unable to decide whether this effect, the data for which were not given, was due to "the after-influence of radioactive substances scattered on the ground", or to the poor hygienic conditions and overwork resulting from participation in rescue activities. Another conclusion of some interest was that the "immediate reactions of fatigue, anorexia, diarrhea, nausea and vomiting" were due to overwork and living under the unhygienic conditions resulting from the bombing. Still another conclusion which was offered was that the thrombocytopenia alone, was not a sufficient explanation for the hemorrhagic tendency which appeared in the patients with evidence of severe radiation injury. The writers believed that their studies indicated that in addition to the deficiency of blood platelets, direct injury to the capillaries, changes in the chemical constitution of the blood, and capillary embolism associated with in active processes must be considered as important etiologic factors in the development of purpura. Extracts from this Paper have been used in several sections of the Report.

(4) "The effect of the explosion of the atomic bomb on the human body" by SURGEON LIEUTENANT MASAO SHIOTSUKI, Omura Naval Hospital.

This paper is one of the few factual reports that could be obtained describing conditions in Nagasaki directly after the bombing. Detailed clinical records of several patients who died in the early stage of the syndrome of radiation injury are presented. This study has been referred to in Section 3N..and..5.N. of the Report. One of the most useful items of information in this essay is the record of the prognosis for patients with severe

radiation injury up to 10 September 1945. Of the 25 patients in whom the syndrome had been recognized, 100% had died. This is a misleading estimate for it is now known that at this same time there were patients in the Omura Naval Hospital who ultimately recovered.

(5) "Report on conditions - 4 September 1945" by LT. COL. YOSHITAKA SASAKI, SURGEON, 216 Temporary Field Hospital (Army).

This report was submitted to the Governor of the Nagasaki Prefecture. It leaves much to be desired for the writer deals in generalities when he should have been able to present facts. The 216 Temporary Field Hospital began to function 16 August 1945, and had provided care for approximately 400 inpatients by 2 September. Up to that time it is stated that 100% of the patients died who developed any of the following: a) severe dysentery-like diarrhea immediately after the bombing; b) continued fever, in excess of 40°C (104°F); and c) hemorrhagic manifestations of any sort.

SPECIAL CLINICAL STUDIES

(6) "Atomic bomb disease in childhood" by members of the Pediatric Clinic (PROF. M. ENJOHJI, Chief) Kyushu Imperial University.

This report is a very brief summary of clinical studies performed on 20 children, 8 of whom were patients in the University Clinic and of which number 3 died. The authors concluded that children were more susceptible to gamma radiation than adults. They either died promptly, or recovered quickly; and the course of the syndrome of radiation injury in them was short and had a favorable prognosis. Unfortunately, there are no data in the paper to support these statements.

(7) "Injuries of the eye due to the atomic bomb", by members of the Eye Clinic, (PROF. S. TAMURA, Chief), Kyushu Imperial University; and

(8) "Anemic retinitis caused by the atomic bomb", idem.

These two reports are valuable because the writers apparently were among the earliest members of the Medical Faculty of the University to arrive in Nagasaki. The types of ocular trauma observed are discussed in four categories:

a) Burns of the lids were mild and tended to heal without deformity. Burns of the cornea and bulbar conjunctivae were infrequent and mild, and healed within a month leaving only slight scars. Superficial Kerato-conjunctivitis due to ultraviolet radiation was observed but healed quickly.

b) Concussion, or air blast caused few injuries, although cases of iridodialysis, luxation of the lens, detachment of the retina and hemorrhages in the retina and vitreous were observed.

c) Trauma due to foreign bodies was neither very common nor unique. The most frequent agent to cause injury was a splinter of window glass.

d) Hemorrhagic retinitis was not observed before the 10th day after the bombing. The lesions were frequently seen in patients with the syndrome of radiation injury. Those hemorrhages and infiltrations were identical with those seen in pernicious anemia, aplastic anemia, and thrombocytopenia purpura.

(9) "Lesions of the pharynx and larynx produced by the effects of the atomic bomb", by M. SASAKI, T. INOUE and S. TORIYA, of the Institute of Otology, Rhinology and Laryngology, Kyushu Imperial University.

This paper contains good descriptions of the lesions that appeared in the mouth, throat and larynx of patients with leukopenia. Two illustrative case histories are included. These describe patients in whom tracheotomy was

necessary because of severe laryngeal edema in one patient and necrotic ulceration of the larynx in the other. (See Section 5N).

(10) "Dermatological conditions produced by the explosion of the atomic bomb", by members of Dermatological Department (PROF. MINAMI, Chief) Kyushu Imperial University.

This paper is a brief survey of the nature of the burns, and of the alopecia of the victims. The fallacious conclusion is presented that patients with burns and radiation sickness had a better prognosis than those without burns. The explanation of this rather common misapprehension is simple: The observations were made 3-4 weeks after the bombing at a time when the patients with severe burns and severe radiation sickness had already died and the surviving burned patients had a milder type of radiation sickness. On the other hand this was a period of high mortality for patients whose sole injury was due to irradiation. The comparison of these two groups was not justifiable.

(11) "The liver function test" (Santonin Excretion) by S. OHKURA, Nagasaki Medical College.

Japanese physicians place much confidence in the Santonin excretion test of liver function. The fact that this test depends on the urinary excretion of a santonin compound elaborated in the liver introduces several variables. The most obvious is anemia; but no effort is made to correct for this, or for any other factor. Forty-nine patients with definite radiation sickness were tested, and abnormal results were obtained in 22. Of 21 control subjects, only one gave an abnormal result. This paper is cited, for it is typical of a number of such reports which purport to prove the existence of hepatic parenchymal damage as a sequel of gamma radiation from the atomic bomb.

(12) "Bacteriological researches on the serum of patients who were injured by the atomic bomb in Nagasaki", by members of the Microbiological Institute, (PROF. R. KIMURA, Director) Faculty of Medicine, Kyoto Imperial University.

The immunologic properties of the sera of 12 patients injured in Nagasaki were studied. Three of the patients had epilation and all were said to have had radiation sickness. The bacteriological power of the sera, tested against staphylococci, dysentery and typhoid bacilli was less than for normal controls. The titre of the complement in each serum was subnormal. On one subject, serial determinations showed increasing values. The opsonophagcytic index, however, was increased when staphylococci and S. typhosa were the test organisms; and was normal with P. pyocyaneus. The technics used were conventional, and the results appear to be valid.

(13) "The bacteriological and seriological researches for diarrhea of atomic bomb diseases," by members of the Pediatric Clinic (PROF. M. ENJOHJI, Chief) Kyushu Imperial University.

Seventeen patients who had had dysentery at any time after the explosion of the atomic bomb were studied. Shigella dysentoriae (type Shiga) was cultured from the stool of one case. Agglutinations against Shiga bacilli were positive in titres in excess of 1:160 in 7 cases; and against "metadysentery" bacilli in one case. In view of the quality of the laboratory work, particularly culture studies, this incidence of dysentery may be considered as minimal. A major problem in the interpretation of the symptoms of victims of the atomic bomb has been the diarrhea. One suspects that much of it was infective, but there are no reliable reports with any bearing on the question.

(14) "Concerning the chemical constituents of the blood of patients injured by the atomic bomb," by R. HIROHATA, T. ODA and M. USUI, Institute of

Medical Chemistry, Kyushu Imperial University.

These authors examined the blood of 38 patients with radiation injury, and conducted repeat determinations on 7 cases. Analyses were performed for the following substances: NPN, protein, albumin, globulin, fibrinogen, calcium and sugar. The most striking abnormality was a reversal of the A/G ratio in all subjects. The deviation from normal which occurred was due to an increase of the euglobulin and a decrease of the albumin fractions. With the passage of time there was a trend of these values toward normal. The values that were reported for serum calcium seem abnormally low. This work, however, appears to have been performed carefully and the reviewer is inclined to accept all of it but the calcium determinations. The values for total plasma proteins agree in general with the determinations made in the Joint Commission's laboratories using the Cu SO_4 Method. Furthermore, the distortion of the A/G ratio, with low values for albumin aids in understanding the subjects who were edematous, but whose plasma proteins (by the Cu SO_4 Method) were not depressed to the "edema level."

(15) "The experimental investigation of the decrease of vitamin C in patients suffering from atomic bomb in Nagasaki", by M. FUJITA, Kyushu Imperial University.

This writer studied the degree of vitamin C saturation by measuring the "fading time" after an intracutaneous injection of a 2.4 dichlorphenolindophenol solution. In general it was prolonged in hospital patients. Improvement in the reaction was observed after treatment with crystalline l- ascorbic acid; or after the ingestion of an extract of persimmon leaves containing vitamin C. The technic is not a very reliable one, but the order of change after medication appears to be significant.

(16) "The pathologic and anatomic changes in atomic bomb disease" by members of the Pathological Institute (Prof. K. OHO, Chief) Kyushu Imperial University.

This paper is a summary of the experience of the group with autopsy material. The general conclusions and observations offered were in close agreement with those of other Japanese workers. Significant differences were noted in three respects:

a) Attributing some of the tissue reactions, particularly the infiltration of plasma cells and eosinophils to an allergy of an unspecified nature.

b) Ascribing changes in the thyroid, pancreas and gastric glands to gamma radiation.

c) Minimizing the extent and significance of changes in the testes.

Specimens of tissue from most of the cases described were given to the Joint Commission, and full details of their interpretation appear in the protocols filed in the Army Institute of Pathology. (General Accession Number: 158930.) Unfortunately, precise clinical details, and information on the location of the subjects at the time of the bombing are generally lacking.

PHYSICAL STUDIES

(17) "Japanese survey of atomic bombing of Hiroshima and Nagasaki," dated 10 November 1945, with corrections of 1 December 1945, reproduced by Hq USSBS, APO 234.

This report is a summary of physical observations and estimates prepared by Japanese nuclear physicists after investigations were conducted in each city. Prof. Y. NISHINA was in charge of the survey. Certain of the data used in the Report are taken from this paper.

(18) "Radio activity of the ground of Nagasaki City and its neighborhood," by members of the Department of Physics (Prof. K. SHINOHARA, Director,) Kyushu Imperial University.

This is a careful study of residual induced and deposited radioactivity, measured with a Lauritsen electroscope. Human bones and samples of earth were collected for analysis at a number of sites near the center. Other measurements were made in the region of the Nishiyama reservoir where radioactivity had been discovered by the party of American physicists from the Manhattan District, Corps of Engineers. The radioactivity near the center is attributed to the action of slow neutrons on elements of the soil. That at Nishiyama is attributed to fission products deposited there by a rainfall shortly after the bomb exploded.

(19) "Investigation of injurious effect on the human body of the explosion of the atomic bomb at Nagasaki City," by members of the Department of Radiology (Prof. Y. NAKASHIMA, Director) Kyushu Imperial University.

This study deals mainly with the ability of concrete and other heavy types of construction, to provide protection from gamma radiation. The amount of concrete which is stated to be sufficient to prevent fatal radiation at an unspecified distance from the bomb is 15-20 cm. The maximum distance at which gamma rays were intense enough to cause death is given as 1000-1500 meters. The report includes the results of studies of individuals who entered the central area immediately after the bombing, but who were outside the city at the time of the explosion. No change in leukocytes, or other evidence of radiation sickness was found in these subjects. The authors believe that induced radioactivity due to neutrons was never great enough to be injurious. The results of blood counts performed on the residents of Nishiyama District (see above) are presented. These subjects had leukocytosis of significant

degree at a period of 50-80 days after the explosion. This is attributed to the effect of radioactive fission products deposited near their homes by rainfall, shortly after the explosion.

(20) "Survey of the effects of radioactivity of the atomic bomb which was used at Nagasaki upon the inhabitants in the district of Chijiwa Town", by DR. S. KATSUKI and other members of the Faculty of Medicine, Kyushu Imperial University.

Chijiwa Town is 32 km. east of Nagasaki, and the cloud containing radioactive fission products passed over it, and enough of these substances fell to the earth that their presence could be detected easily by a Geiger counter. The course of the cloud and the urban regions with detectable radioactivity were discovered by monitors from the Manhattan District, Corps of Engineers, during their survey in September, 1945. Clinical studies were made of 214 residents of the town, as well as 56 natives who had been in Nagasaki City on 9 August. The residents complained of diarrhea, fever, etc., but there was no leukopenia, or epilation, or purpura, and a careful search revealed no cases of radiation sickness.

(21) "Survey of the radioactivity influence caused by the atomic bomb which was used at Nagasaki, upon the inhabitants of the City of Shimabara," by S. OSAJIMA and E. KO, Nagasaki Medical College.

The radioactive cloud also passed over Shimabara City and measurements of the ionizing radiation on the ground were higher than normal. There were no patients with radiation sickness nor any doubtful cases in this town. Blood examination of 15 persons who were in Shimbara 9 August revealed normal values.

MISCELLANEOUS

(22) "Report of a case of monocytic leukemia occurring following the

atomic bomb disease," by Drs. T. MISAO, Y. HARADA and J. HATTORI.

This case is A.M.M. -158930-224. See protocol for details. (8)

(B) Work done by Japanese members of the Joint Commission.

GENERAL CLINICAL STUDIES

(23) "Contributions to the problem of the cause of death of the atomic bomb victims," by T. KASHIMADO, Tokyo Imperial University.

This is the report of a study of the clinical records of the Omura Naval Hospital to determine the apparent cause of death among the patients treated there. Of the 164 deaths that occurred between 9 August and 17 September, 89 were patients whose only injury was burns; 39 had only wounds; and 36 had some combination of injuries due to burns, wounds and radiation. The writer experienced great difficulty in establishing a relationship between radiation injury and death in patients with other types of injury. It is possible that more extensive laboratory studies could have permitted the making of clearer distinctions of the cause of death, but the case load was so great that this was not done.

(24) "Concerning the cachetic conditions of patients injured by the atomic bomb in Nagasaki," by M. URABE, and M. MENJO, Surgical Clinic, Tokyo Imperial University.

This is a careful study of 15 patients who displayed a peculiar type of cachexia which was distinctive enough to justify considering it as a clinical entity. The typical subject was of middle age and had been out of doors or inside a wooden building at a distance of 1 to 2 km. from the center of the explosion. Twelve of 15 had received flash burns of moderate extent and severity, but healing occurred satisfactorily. Six of 15 had epilated and all the subjects had developed oropharyngeal inflammations, or purpura, or both. Thirteen of 15 had developed diarrhea, which was severe, often

bloody, and quite resistant to therapy. Progressive anemia was observed in every case and the values for the hemoglobin content and the red cell count were less than half of normal. Leukopenia had been observed in some of the patients; but at the time of the study, (60-90 days after the bombing) all had normal white blood cell counts. Examination of sternal marrow obtained by puncture biopsy was performed in every case. The marrow contained fewer erythroid elements and fewer eosinophils than were seen in patients assumed to have received equivalent doses of gamma radiation. Hypoproteinemia was observed in all the cases; the average value for plasma protein concentration ($CuSO_4$ Method) was 5.4 G. per 100 cc, and the range of values was 3.9 to 6.4G. Fourteen of the 15 had edema of some degree, in half of them it was generalized and associated with ascites. Loss of weight, dry skin, low body temperature and low blood pressure were the other features of the syndrome. Seven of the subjects died and were autopsied (A.M.M. Numbers 158930-184, 190, 192, 193, 194, 195, 196). These patients showed little tendency to recovery, even when provided with sufficient food, vitamin supplements and appropriate drugs. The writers conclude that the syndrome is a "traumatic cachexia" and seem to feel that loss of protein, diminished resistance to infection, and an unspecified type of damage to other structures by the gamma radiation were the important etiologic factors. Patients with this syndrome of cachexia attracted considerable attention from all observers, but the percentage of the surviving hospitalized victims who had this condition was quite small, less than 10% of the total.

SPECIAL CLINICAL STUDIES

(25) "The behavior of the eosinophilic cells in blood and bone marrow of the patients injured by the atomic bomb at Nagasaki in the third and fourth month after the explosion," by H. UEDA and S. NIKAIDO, Faculty of Medicine,

Tokyo Imperial University.

Eosinophils in the blood and in the material obtained by sternal punctures was frequently found. There appeared to be a definite relationship between the process of recovery from the syndrome of radiation injury and the degree of eosinophilia. The highest values for the percent of these cells in the blood and marrow were observed during October, that is, in the period 7 to 12 weeks after the bombing. A condensation of a tabulation of the results of the study is shown in Table 1.

TABLE 1

GROUPS	No.	MAXIMUM DISTANCE METERS	EOSINOPHILIA IN BLOOD OVER 10%	MAXIMUM VALUE IN BLOOD FILMS
A. Patient with clinical evidence of radiation injury, severe type with epilation.	50	0-2500	75%	39%
B. Patients with clinical evidence of radiation injury, mild type without epilation.	590*	0-4000	40%	54%
C. Uninjured subjects "Controls"	50	4000-4700	40%	22%
D. Controls	15	4700-plus	20%	14%

In Group A, 8 of the 50 patients had less than 10% eosinophils in the peripheral blood. Five of these 8 patients died; and they were the only deaths in this entire group. The percentage of eosinophilic cells in their marrow was:: 0%, 0%, 0%, 0.4% and 0.8% respectively. This may be compared

*Refers to total number of blood counts on approximately 270 patients.

with the average for all subjects biopsied in October: 5.5%, and for normal Japanese: 4.3%. It is interesting too, to note that the myeloid-erythroid ratio in the marrow of the fatal cases was high: 5.1 to 21:1; as compared with the average for this same period which was 2.5 : 1. The authors believed that persistently low values for eosinophils in blood and bone marrow was an ominous prognostic sign. The same was also true for high values for the myeloid: erythroid ratio in the differential count of sternal marrow cells.

(26) "Report of reticulocytes" by K. KAIDA et al, III Medical Clinic Kyushu Imperial University.

This is a report of 161 reticulocyte counts performed on the blood of patients in Omura Naval Hospital. The most striking feature of the study was the low percentages found. In patients whose red cell count was less than 2,000,000 per cubic millimeter, the usual value was about 4.0% which was the highest for any level of red cell count. When the results were tabulated on the basis of the nature of their injuries, the group who had both hemorrhagic manifestations and burns had the largest number of reticulocytes: average value 4.9%. In general a tendency was observed for the reticulocyte count to vary in the same direction as the leukocyte count. This work was carefully done and illustrated quite well the meagre degree of erythropoiesis that occurred spontaneously. Except for one patient, no reticulocyte count higher than 5% was found. In other hospitals where potent liver extract was used in therapy, values as high as 15% were observed in comparable patients.

(27) "Report on basal metabolism," by K. KAIDA et al., III Medical Clinic, Kyushu Imperial University.

This report is of no scientific importance, since the estimates of basal metabolism were made on the basis of the relationship between pulse rate and pulse pressure. It is mentioned here only because the method appeared to be

common practice in Japan. Either Read's or Gale's formula was used. The degree of confidence of Japanese physicians in this method was quite amazing.

(28) "The influence of the atomic bomb explosion on the ear, nose and throat", by Y. KASHIWADO, Otorhinolaryngology Clinic, Tokyo Imperial University.

This is a series of four reports describing the results of careful examinations of the ear, nose and throat of 198 patients. The types of lesion observed were classified as follows:

a) Deformity of the auricle-caused principally by flash burns and perichondritis.

b) Rupture of the ear drums-caused by air blast.

c) Atrophic rhinitis - in most instances this involved the anterior portion of the nose. In some cases this lesion was associated with flash burns of the face.

d) Tinnitus - said to have been present since the bomb exploded. In the majority of these patients there was no hearing loss.

e) Deafness - said to have been present since the bomb exploded. In most patients this was apparently due to stricture of the eustachian tube.

The exact location of all patients, and in particular those with ruptured ear drums was investigated with the following result; (See table 2.)

TABLE 2

TYPE OF PATIENT	LOCATION IN RELATION TO BOMB		
	0-500 meters	500-1000 meters	Farther than 1000 meters
Ruptured ear drum, due to bomb.	1	4	0
Ruptured ear drum, probably due to bomb.	3	6	0
Total cases	44	125	29
Total percent with ruptured ear drums	9%	8%	0

The writer consulted Japanese engineers who supplied the following data for the blast pressure at Nagasaki. (see table 3)

TABLE 3

DISTANCE - METERS	HYDROSTATIC PRESSURE GM. / CM^2
400	2000
500	1000
1000	130

Experimental work is cited which illustrated the effect of hydrostatic pressure on the ear drums of cadavers:

a) 1 atmosphere of over-pressure (1000 GM/cm^2 caused the rupture of 10.8% of 180 ear drums.

b) 380 GM/cm^2 was the lowest pressure which ruptured an ear drum. The author concluded that the ruptured ear drums that he studied were due to the exploding atomic bomb.

(29) "Gastrointestinal tract of the atomic bombed patients," by K. KISHIMOTO, Faculty of Medicine, Tokyo Imperial University.

Careful studies were made of the gastric secretions of 45 patients with the syndrome of radiation injury. Anacidity, even after histamine, was found in 6, but since these were older patients, no significance was attributed to it. Fluoroscopy of the stomach and small intestines was practiced on 11 patients. No abnormalities were seen. Gastroscopy was performed on 20 patients, and the appearance of the mucosa was reported to be within the limits of normal. The patients who were studied were in the group most severely affected by the gamma radiation who were still alive in October 1945 (8-12 weeks after exposure) and who were able to tolerate the studies. The failure to find significant lesions in the stomachs of these patients is an important observation. Other less critical Japanese have described a variety of "specific lesions."

(30) "Investigation of changes in menstruation caused by injury from the atomic bombing at Nagasaki," by K. Kaida, et al., III Medical Clinic, Kyushu Imperial University.

This study was made between 1 November and 20 November 1945. Questionnaires were answered satisfactorily by 47 females, mainly school girls between the ages of 15 and 20. All except 61, who were hospital

patients, were healthy at the time of the study. The entire group were within the city limits on 9 August 1945. The most marked effect on menstrual function was seen in the women who had the syndrome of radiation injury, with epilation and/or purpura. (See table 4). Of the entire group, the 326 who were outdoors, or inside of Japanese type wooden buildings were found to have been affected the most consistently. The details of this are presented in condensed form in Table 4.

(31) "Report of miscarriages and premature parturitions" by K. Kaida, et al., Faculty of Medicine, Kyushu Imperial University.

The effects of the atomic bomb on pregnancy was studied with the help of approximately one-third of the local obstetricians and midwives. These specialists had attended 182 women in the period 9 August to 8 November 1945. Of these pregnancies, 50, or 27.5% terminated abnormally. According to their clinical records, during the period 9 August 1944 to 8 August 1945, 99, or 6.1% of the pregnant women they attended had miscarriages or delivered prematurely. Of the 50 abnormal cases, studied by Kaida, five were attributed to factors not related to the atomic bomb.

The findings for the group are condensed in Table 5.

TABLE 4
(Women who were outdoors or inside wooden buildings.)

DISTANCE FROM BOMB	TOTAL NUMBER OF FEMALES	% WITH CHANGE IN MENSTRUATION	% WITH AMENORRHEA FOR MORE THAN 1 MONTH
0- 0.9	11	100	82
1.0- 1.9	80	88	75
2.0- 2.9	50	66	62
3.0- 3.9	83	49	32
4.0- plus	102	26	18
*Patients with radiation sickness	40	100	92

(The location of these varied.)

TABLE 5

DISTANCE FROM BOMB	NORMAL DELIVERY	MISCARRIAGE	PREMATURE PARTURITION	
0 - 0.9 km.	0	5	0	
1.0 - 1.9 "	0	8	6	
2.0 - 2.9 "	5	14	1	
3.0 - 3.9 "	32	3	0	
4.0 - plus	95	3	5	
Totals	132	33	12	Total-177
Cases presumably not due to the bomb.		3	2	

There were insufficient data to provide significant information on the amount of protection against miscarriage that heavy building construction might offer. Thirteen of the women were in concrete or brick buildings, or in shelters, and of these, 4 miscarried. The distance from the bomb in two cases was less than 1000 meters. Ten of the 45 mothers died after parturition, and all but 2 of these died within one week. Of the 12 premature infants that were delivered, 4 were still born and 3 died subsequently.

(32) "Chlorine content of the blood of the atomic bomb patients in Omura Naval Hospital," by S. HINO, Faculty of Medicine, Tokyo Imperial University.

Whole blood chlorides were estimated in 190 patients, using a micro-method (Koranyi Rusznyak the normal values for which are 450-500 mg. per 100 cc. Fifteen of the patients were found to have whole blood chloride values less than 450 mg. %; one was as low as 380 mg.%. These subjects with low values were studied for clinical evidence of adrenal insufficiency with negative

*Note: The patients are included in the first group of figures if they were outdoors, or in wooden buildings.

results. The above chloride investigation was undertaken, actually, to determine the incidence of adrenal dysfunction after gamma radiation.

(33) "The Takata test for hepatic function of patients injured by the atomic bomb" by K. KISHIMOTO, Faculty of Medicine, Tokyo Imperial University.

The Takata test was performed 566 times on 347 patients, of whom 148 had definite evidence of injury by gamma radiation, as well as other injuries. Seventy-two of these patients had not been burned. Seventy-three of the total number had burns as the main injury, but in them there was reason to believe that radiation may have been a factor in their illness. The remaining 126 had received no burns, and presumably no injury by gamma rays. The results were as given in Table 6.

The tests were performed serially in some patients, and at different intervals after the bombing. Between 30 September and 11 November, there was no significant variation in the percentage of positive tests among the groups tested. The large number of positive tests encountered in this series is interesting; but the tabulation does not prove that gamma radiation caused liver dysfunction. These studies were careful and the reviewer has considerable confidence in their accuracy. This type of result has convinced many Japanese that the liver is damaged by gamma radiation. (see table 6).

(34) "The examination of urine" idem.

The urine of 229 patients was tested for urobilinogen and albumin. The urobilinogen excretion was significantly elevated in 31 or 13% of the patients. When the data are analyzed, it is found that 13% of patients whose only injury was due to gamma radiation had significant urobilinogenuria at the time of examination. The findings with respect to albumin were similar: 17.5% if the 229 patients were found to have albuminuria at the time of examination.

Among the patients with injury from gamma rays, but without burns, 10 of 47, or 21% had albumin in the urine. The writer believed that the "high" incidence of urobilinogenuria was good evidence for hepatic parenchymal injury by gamma radiation. After analyzing the results on the basis of the diagnosis, the only justifiable conclusion is that urobilinogenuria occurred to the same extent in patients severely injured by gamma radiation and in patients with burns and other types of wounds.

TABLE 6

TYPE OF PATIENT	NUMBER	% WITH POSITIVE TAKATA TEST
1. Clinical syndrome of radiation injury, with or without other types of injury.	148	49%
2. Radiation injury-without burns.	72	48%
3. Burns, with or without wounds, but no clear evidence of radiation injury.	73	55%
4. Mechanical injuries & other conditions.	12	33%
5. Normal controls	52	1.1%

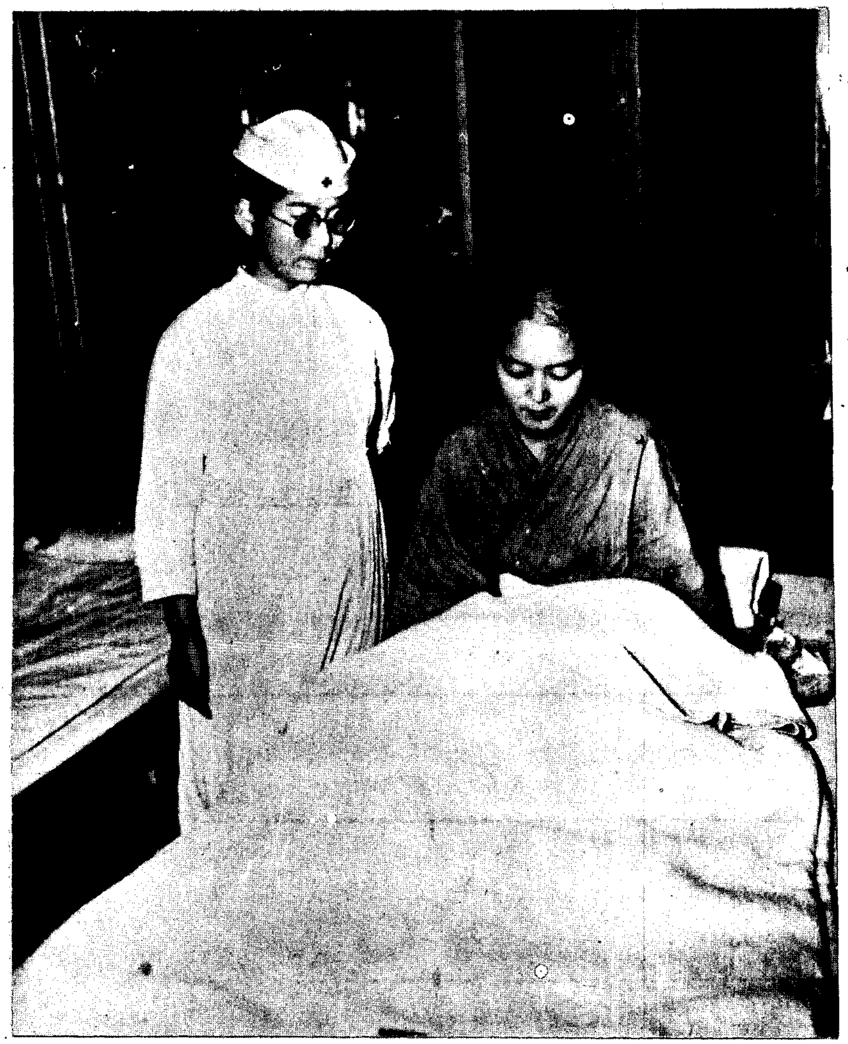


Fig. 1--(4N). A patient and a Red Cross nurse in one of the wards of Omura Naval Hospital. The beds and the general cleanliness were unusual features of this institution. (Photo File #NH 138.)

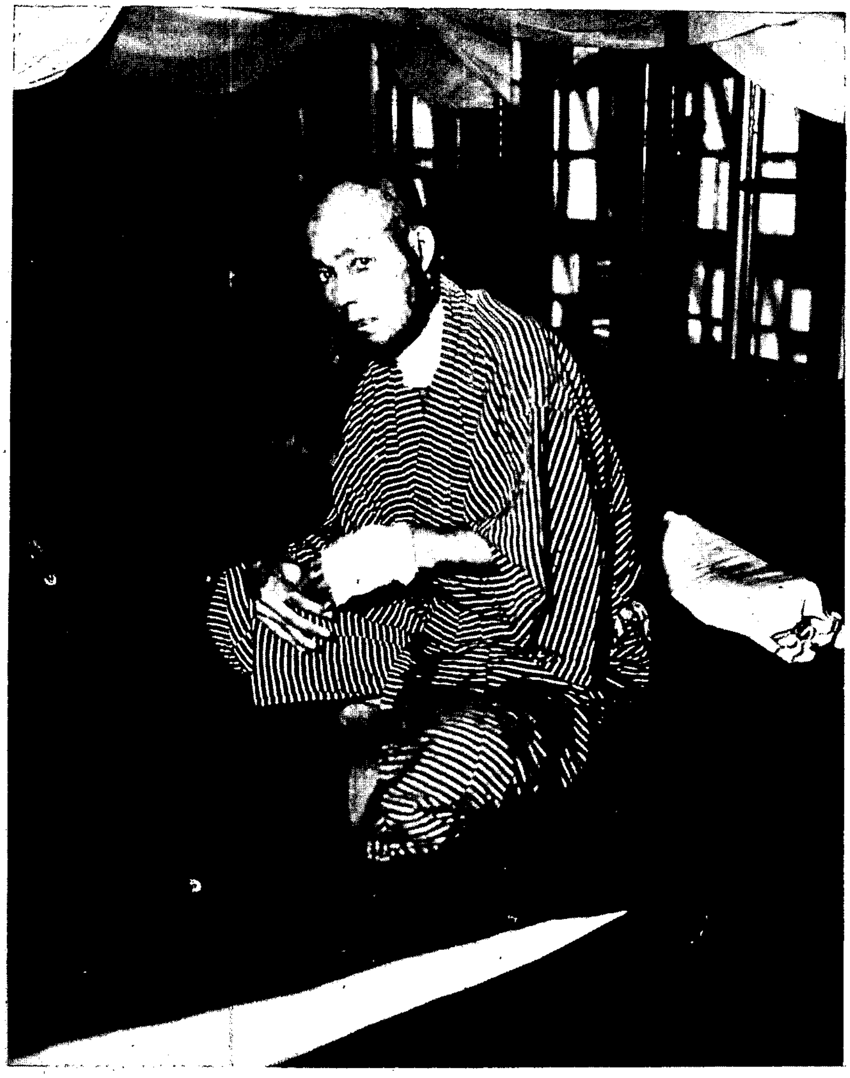


Fig. 2--(4N). Scene in a ward of Omura Naval Hospital. (Photo File #NP 156(K).)

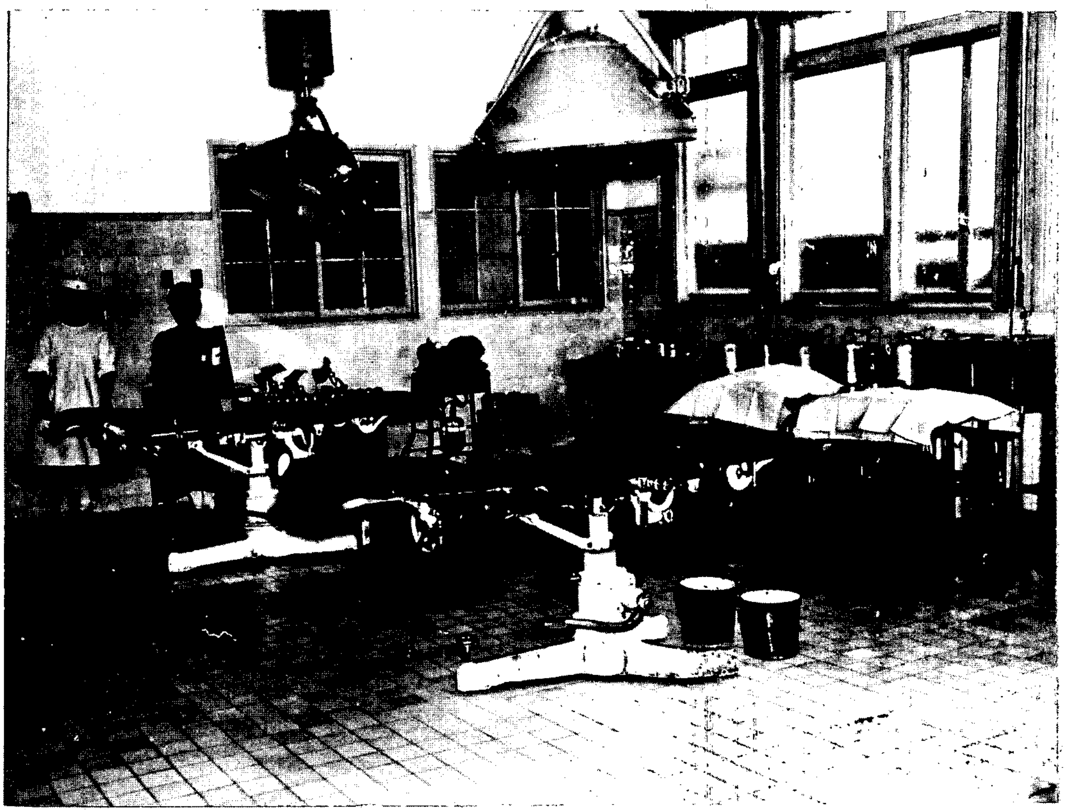


Fig. 3--(4N). A view of one of the well-equipped operating rooms in Omura Naval Hospital. (Photo File #NH 137.)

Fig. 4--(4N). Laboratory, Omura Naval Hospital. (Photo File #NH 136.)

Fig. 5--(4N). Laboratory, Shinkozen Medical Aid Hospital. (Photo File #NH 139a.)

Section 5H

CLINICAL OBSERVATIONS IN HIROSHIMA

Prepared by Averill A. Liebow, Lt. Col., M.C.

Data collected by Verne R. Mason, Col., M.C., Averill A. Liebow, Lt. Col., M.C., Milton L. Kramer, Major, M.C., Jack D. Rosenbaum, Capt., M.C., Calvin O. Koch, Capt., M.C., J. Philip Logo, Capt., M.C., and Japanese Members of the Joint Commission Team in Hiroshima.

To resolve the complexities of the clinical observations it was thought best to present the information in sections. Each chapter gives a detailed account of certain aspects, but cross-references are abundantly employed in an attempt not to dismember the clinical whole. In the present section the main signs and symptoms are discussed and illustrated systematically and a broad classification of the types of cases commonly encountered is presented, together with illustrative examples. All available hematologic and necropsy data were reviewed by the Commission and are presented in sections 6, 7, and 8. In section 9 appears a statistical analysis of the case records obtained as detailed in section 4. For the clinical details of the early cases reliance has had to be placed on the Japanese descriptions as contained in reports from the Tokyo First Military Hospital and Tokyo and Kyoto Research Parties. Abstracts appear in the appendix on Section 4H.

The various types of injury will be discussed according to the classification contained in table 1.

A. Trauma

Nature of the Injurious Factors: Trauma was inflicted by the mechanical force of the explosion either as blast or indirectly. As in the case of the bombing of Britain the latter was much the more important.

What is known concerning the exact magnitude and duration of the mechanical force exerted during the explosion of the atomic bomb at Hiroshima

TABLE 1

MEDICAL EFFECTS OF ATOMIC BOMB

Energy	Injury	Type or Target of Injury
I Mechanical	A. Trauma	1. Direct (Blast) 2. Indirect (Falling Debris)
II Radient a. Infra Red) b. Visible Light) c. Ultra Violet)	B. Burns	1. Direct ("Flash burns") 2. Indirect (Flame burns)
d. Gamma Rays (et al)	C. Radiation Effect	1. Skin 2. Gastro-intestinal Tract 3. Gonads 4. Lymphoid tissue 5. Marrow

is still secret. It may, however, be discussed in general terms based on rather crude observations and analogies.

In the case of an ordinary explosion* of say 70 lbs of HE there is at a distance of 30 feet from the explosion point a sharp peak of high pressure lasting 5 milliseconds followed by a negative phase approximately 30 milliseconds in duration. At this distance (30 feet) the peak pressure is only 15 lbs per sq. in. in excess of atomospheric. It rises rapidly closer to the center. "Small animals may be killed instantaneously at pressures of 50 lbs., and are certainly killed at pressures approaching 100 lbs per sq. in.*" With any given charge of explosive, the duration of the pressure peak increases and the pressure falls with distance.

The atomic bomb explosion differed from ordinary bomb blast in the wide compass of its range. No one was closer to the bomb than several hundred meters. At that distance the peak pressure must already have fallen, and its duration must have been greatly increased in comparison to what it was near the center. The explosion did not have the hammer-blow effect of high explosive, but was rather like a sudden violent gust of air which lasted for a brief, but appreciable period. As in the case of an ordinary explosion the speed of the pulse of positive pressure was approximately that of sound beyond a certain distance, but was much greater close to the point of origin.

* Zuckerman, S. The problem of Blast Injuries. Proc. Royal Soc. Med. (Sect. Surg. and Path), 34: 171-188, 1941

According to Japanese investigators the mean velocity of the blast wave over a distance of approximately three kilometers was about twice that of sound. Its duration, at 400 meters, was estimated as approximately one-twentieth of a second. The pressure of the blast at Hiroshima was in the neighborhood of 14.2 pounds per square inch at 200 meters, 5 pounds per square inch at 500 meters, and 2.1 pounds per square inch at 1,000 meters. It now remains to discuss the direct and indirect effects of the blast on the human target.

a. Direct Effects.

The Japanese medical observers on the spot could not find any cases of direct damage to the internal organs by the blast. At necropsy of the early cases there were no typical evidences of blast damage to the lungs, although foci of emphysema and atelectasis were found.

Many individuals (approximately 7% of survivors up to 2500 meters), reported having lost consciousness temporarily with no history of direct trauma to the head. The observations of Zuckerman* tend to discount cerebral concussion resulting directly from blast. It is probable that violent displacement by blast of many people accounted for trauma to the head with resulting unconsciousness.

Ruptured Ear Drum: At the Ninoshima Hospital soon after the bombing only 8 of 371 patients who were examined had ruptured ear drums, although 19 in the group of 371 suffered temporary deafness. Seventy-six per cent of this group of men had been within 2 kilometers of the center. In the patients

*Zuckerman, S. "Observations on So-called Blast Cerebral Concussion (Confidential British Report, B. P. C. 147/W.S. 12)

examined by the Joint Commission less than 1% had ruptured drums, even within the first 1000 meters, and beyond 1500 meters the incidence fell below 0.1%. According to the British investigators there is great variation in what blast pressure will result in rupture of the ear drum in man. In explosions where persons were subjected to pressures estimated at between 45 and 100 pounds per square inch, less than half of a small group suffered rupture of the tympanum. The drum may however rupture under pressures as low as 2 to 4 pounds in excess of atmospheric.* Factors of acceleration of pressure may also be important in determining the incidence of blast effect on the biological target.

b. Indirect Effects of Blast (Trauma by falling walls, etc.).

Range of Effect, Incidence of, and Mortality from Injury: Windows were broken as far away as Kure 20 Km. The radius of complete collapse of wooden native buildings was 2.4 kilometers, almost symmetrically distributed about the center. Its extent is shown in figure 7 (Section 3H). The incidence of mechanical injuries depends on distance from the center and is shown graphically in figure 2H (9). It is about 60 per cent between 500 and 1250 meters. The possibilities for injury are illustrated in before and after photographs and panoramic views in Section 3H.

It is only beyond 2700 meters that the incidence of mechanical injury begins to fall off rapidly. Even at 4500 meters the incidence in the survivor group is still 14 per cent. Fatal injuries, however, are almost entirely in the zone of complete destruction of buildings (figure 3 (10H)).

*Blake, P.M., Douglas, J.W.B., Krohn, P.L., & Zuckerman, S. Rupture of the Ear-Drums by Blast. Military Personnel Research Committee of the Medical Research Council. (Confidential British Report, B.P.C. 43/179/W.S.21).

Beyond the 2400 meter range there is a very large zone where there are partially collapsed wooden buildings or where an occasional building has suffered total collapse. This explains why the curve of casualty and mortality from injury does not quite reach the base line even at 5000 meters.

From the point of view of avoiding mechanical injury the best position, as a moment's thought would lead one to expect, proves to be out of doors at a distance from buildings (figure 4H(9)). This is true for survivors, although of course in the inner ring the mortality among those truly in the open from "flash burns" is very great. Those indoors in heavy buildings, surprisingly, show a higher incidence of injuries than those in native Japanese buildings. Since most of the injuries were inflicted by glass, however, and the concrete buildings have more glass than those of native type the explanation of the paradox is clear. Furthermore, this ratio of injury applies only to non-fatal injuries in survivors as can easily be seen from figure 11 (10H). Here it is obvious that the total mortality from immediate trauma is higher in the Japanese buildings than in the concrete buildings at the same distance. The reason is that over the wide area of impact the Japanese buildings collapsed from blast while the concrete buildings generally retained their structural integrity.

Exactly how much is contributed to the total mortality by the traumatic factors will never be known. Obviously in brick and concrete buildings that suffered partial or complete collapse the mortality was enormous. In the collapse of the Japanese buildings the great tree beams and the tiles were

the usual factors in producing injury and in trapping the occupants. The important thing is not so much the actual immediate injury as the fact that the city was swept by fire before rescue operations could be instituted. Consequently, even though mechanical injury was not directly responsible for death, it probably contributed vastly to the actual mortality. Particularly those who had suffered concussion or fracture or who had been rendered helpless by severe injuries of the extremities or even those who were merely pinned beneath the wreckage, were soon lost in the flames. This accounts for the low incidence of the severe forms of injury among the survivors.

Types and Mechanisms of Injury. The incidence of various types of injury is given in the statistical section (Section 9). In one group of patients* seen at a Japanese military hospital they were as follows:

Fracture	11	11.5 per cent
Contusion	51	53.8 per cent
Laceration	33	34.7 per cent
Total	95.	100.0 per cent

Lacerations were the most common forms of injury. They were usually inflicted by glass or occasionally wooden splinters or metal were concerned. A typical source of such glass fragments is illustrated in figure 24 (Section 3H), and some typical injuries are shown in figures 1 to 5. Characteristically the lacerations were small and multiple, but occasionally heavy fragments produced deep incised wounds (figure 3). When the fragments were small, clothing was sufficient to protect. This proved to be the case even as close as 1000 meters, as in patient Takatani (figure 1).

*Appendix 4H, Ref. (1).

Here, although the glass did not penetrate the patient's trousers, it struck with sufficient force to pierce the skin and to produce an aneurysm of the radial artery (figure 2). In other instances, however, at comparable distances or beyond, the glass was projected with sufficient force to penetrate several layers of clothing (figure 58). Even at 4 kilometers, however, Father Siemes describes how the glass became embedded in the opposite wall of a room in which he was standing. Probably the directness of impact of the blast wave, the initial resistance of the glass, and other factors are at play in determining how much injury will be inflicted.

The incidence of fractures in survivors is low. It was only 4.5% in the patients studied at Hiroshima by the Joint Commission. One of the rare fractures among survivors is illustrated in figure 5. Such lesions did not do well since little orthopedic and almost no physical therapy were applied. Most of the injuries of this type were inflicted by trauma of the heavy roof beams in the otherwise fragile houses (figures 20 to 22, Section 3H).

Complications. A description of the state of the course of the lacerations in patients with fatal radiation disease is quoted directly from a report of the Tokyo 1st Military Hospital: "Healing of wounds was prolonged coincident with the appearance of typical symptoms (of radiation effect); the granulation tissue became anemic and edematous. It bled easily or became dry because of unusual decrease of secretions. The borders of the wound were undermined; and growth of granulation tissue stopped and no tendency to heal was shown. In other cases the wound enlarged gradually until death. In those who survived the granulation tissue improved again following recovery from radiation effect."

Bacterial Infections. Little diagnostic bacteriological work was performed. In a group of 169 injuries, multiple abscesses developed in five and erysipelas in three. The incidence of gas gangrene and tetanus is uncertain.

B. Burns

The burns that occurred can be classified as "flash burns", which are the results of the direct action of radiant energy, and flame burns. The latter are relatively rare for the reason that it took some time, perhaps one-half hour, for the fires that were started following the blast to spread within the city of Hiroshima. Those who could not escape were burned to death. Some patients were burned by flame when their clothes caught fire.

The radiant energy covered the entire width of the spectrum which resembled that of the sun. In this section the band above that of the gamma rays to the high infra-red will be considered. This includes the ultraviolet, visible light, and infra-red rays. The exact intensity of these various components of the spectrum cannot be stated. None of these has a high degree of penetration so that any solid object, or under certain circumstances, even leaves or cloth was sufficient to produce a shadowing effect. This is illustrated in a series of photographs (figures 6 to 24). Evidence of shadowing by human forms is presented in figures 19 to 23 where the outlines of men, who were in the direct line of the rays, have been projected upon the asphalt of the Bantai Bridge. The angles of the incidence of the rays are indicated by the direction of the shadows, and thus, by triangulation, the location of the actual airburst of the explosion was determined (see figure 9 and compare figures 15 and 18).

Only surfaces directly exposed to the rays are affected by them, and there results, so to speak, a "profile burn." This is particularly striking in a case of such objects as the fruit illustrated in figure 24 and the patients who will be discussed subsequently.

<u>Duration of the Flash.</u> The duration of the flash can be estimated, within relatively broad limits, from data at hand. The maximum duration can be deduced from the fact that there was sufficient heat at the Gokoku Shrine, 650 meters from the airburst of the explosion, to alter the surface of granite before the upright shadowing columns had toppled from the blast (figure 7). The sharpness of the shadow indicates that the peak intensity of heat had exerted its effect by the time the columns were knocked over. Assuming that at that range the blast wave had at least twice the velocity of sound, it arrived at the shrine within 0.75 seconds. Consequently this is the maximal period of action of the heat. The minimal period is indicated by the fact that some patients had time to close their eyelids before they were burned. It is estimated that this process takes approximately 0.01 seconds. The brief duration of the blast is confirmed by the sharpness of the shadows of such constantly moving objects as leaves projected upon wood behind them (figure 6).

Most of the heat radiated from a relatively small center, but double shadows in some places indicated the existence of an umbra-penumbra effect. This has been ascribed to a "ball of fire," i.e. a relatively large mass of material emitting radiant heat sufficient to produce changes in some substrates.

The temperatures reached at various surfaces are of interest. They

depend on the specific heat of the materials concerned. In the case of the granite of 650 meters from the bomb, Japanese investigators have estimated that a temperature of 2000 to 2500° centigrade acting for approximately one second was necessary to produce the change observed. The wood of dark colored telephone poles was superficially carbonized at 3000 meters from the center. From the data of Ashe and Roberts* a temperature of 400 degrees centigrade acting for approximately 0.5 seconds is necessary to produce a second degree burn. The exact number of calories absorbed by various surfaces exposed to the bomb at Hiroshima are not exactly known, since the duration and intensity curve of the heat flux are matters of conjecture. Nevertheless, from the effect discussed in the preceding paragraph it is clear that the injurious agent was of extreme intensity and of very short duration.

The conditions of heat absorption at approximately 3300 meters were sufficient to result in second degree burns (erythema and blistering) by the next day. In completely exposed individuals at closer ranges, second or third degree burns were found. The morphology of the burns in relation to distance and the influence of clothing are discussed later.

Incidence and Mortality. Distance and shielding were among the determinants of the incidence of burns as shown in figure 3H of Section 9. One of the notable features of the incidence curve of those in the "outdoors unshielded" group among the 20-day survivors is the rise that takes place from just over

*Ashe, W. F., and Roberts, L. B.: Experimental Human Burns (Partial Report). War Med., 7: 82-83, 1945.

60 per cent at 500 meters, to approximately 75 per cent at 1750 meters. This doubtless results from the high mortality incident to exposure to burns close to the bomb. Thus only partly shielded individuals (who thought they were unshielded) are represented in the left end of the curve. From study of certain groups it is apparent that the mortality among those out of doors who were truly unshielded is close to 100 per cent.

Burns were also remarkably common among those indoors. It can be assumed that since it was summer the windows in many houses were open. Evidence has also been presented by the Japanese that burns occurred even through window-glass, as in the modern concrete building of the Hiroshima Post Office Savings Bank* at 1700 meters. The windows in this building are illustrated in figure 11 with the shadowing effect produced by the frame.

The incidence curve also shows that even in the "unshielded", burns no longer had a significant incidence beyond 4000 meters. Beyond 3000 meters few burns required treatment, and they were merely manifested in erythema without vesiculation.

Accurate information is available from several sources concerning mortality from burns among those in the direct path of the radiant energy from the bomb. At 750 meters all 51 of a group of girls of the Hijiyama High School died. They were at morning ceremony near the Emperor's tree at Chugoku Headquarters. At 1000 meters only 10 of a group of 193 workers from Otake Village survived (mortality 94.7 per cent). This is comparable to that of a large number of school children who were out of doors removing

*Appendix 4H, Ref. (1)

debris from an area that had been cleared for firebreaks (figure 9 (10H)).

At 2400 meters, the only other point at which accurate data is available, the mortality in a large number of persons who were burned on the Koi Bridge was under 2 per cent (See Section 10H, Mr. Hino's group of the Otake Workmen's Party).

An observation of great interest made on Hiroshima school children is that the mortality in the large exposed group fell only slightly (to 83.7 per cent) up to 2000 meters, and then beyond this, fell precipitously (figure 9, Section 10H), to 14.5 per cent. This sharp drop is probably associated with a decrement in two factors. a. the lethal effect of the thermal injury; b. the injurious effects of the gamma rays, that at least indirectly, through the resultant infection and leukopenia in exposed persons, influenced the burns.

Treatment and time of Death. Several records are available concerning the time interval between exposure and death in the burned patients. Such records are significant only when they have reference to the particular group at a known distance from the center. In the case of the 51 girls from Hijiyama High School the mortality curve is as follows:

TABLE 2

HIROSHIMA - MORTALITY STATISTICS OF HIJIYAMA HIGH SCHOOL, GIRLS

Group	Date and Day						
	6 Aug. (1)	7 Aug. (2)	8 Aug. (3)	9 Aug. (4)	10 Aug. (5)	11 Aug. (6)	12 Aug. (7)
1	2	6	6	6	2	3	1
2	8	1	9	3	2	2	0
1 & 2	10	7	15	9	4	5	1

In a group under treatment at the Kameyama Hospital, who had received burns at a distance of approximately 1 kilometer, the peak incidence of deaths was on the fourth day (11.9 per cent). Fifty-three and one-tenth per cent died within the first week, and 75 per cent of the total within two weeks. Statistics to be presented later show that there is another peak in deaths in the third and fourth weeks when the radiation effects are at their greatest.

Effect of Radiant Energy upon the Eye. Direct injuries of the eye were remarkably few. Colonel Verne Mason interviewed the Japanese ophthalmologist Takehisa Oguchi at Kaijinkai Hospital at Kure. Only referred cases had been sent to this ophthalmologist who had examined between 20 and 30 fundi. He had seen only 4 or 5 palpebral burns. The shadowing effect of the supra-orbital ridges and the blink reflex helped to explain this finding. The effect of rapid closure of the eyes, as demonstrated in figure 41, probably helped to prevent serious injury. Almost all of the patients had had a temporary amblyopia. In no case in the experience of this physician did this exceed a duration of five minutes. Two patients had had conjunctivitis and keratitis resulting from exposure to the blast. The patient illustrated in figure 25 is unusual on account of the long duration of the keratoconjunctivitis. There was only one patient with a permanent scotoma from perforation of the macula. There were three patients who had had a central relative scotoma with commotio retinea and opacities (Berlinsche Trübungen) about the macula who recovered. Two patients exhibited prolapse of the iris and a traumatic cataract following contusions of the eyeball. There was only one who had a band-shaped, horizontal, equatorial burn of the cornea.

The group from the Tokyo 1st Military Hospital investigated 132 patients fundiscopically between the middle and the end of September. Thirty-two of the patients had other evidences of radiation effects. In all, 300 patients were questioned and less carefully examined. One case was found to have a cataract and dimished visual acuity. A slight reduction in the transparency of the cornea was observed in some men, but they had no subjective difficulties.

One patient was so blinded by the flash that he was unable to distinguish light from dark for approximately three days, but he recovered vision. There was some slight opacity of the anterior and posterior surfaces of the lens in that case. Eight patients in the group had hemorrhagic flecks or white spots thought to be organized petechiae. These were considered to be associated with the aplastic anemia of radiation effect and are part of a more general disturbance that will be discussed below.

The injuries observed in a group of survivors are tabulated in Section 9.

Burns of the Skin. Since the intensity of radiations of the wave-length of ultraviolet or higher varies inversely with the square of the distance, it would be expected that proportional damage to the skin would result. As it happens, among the survivors the burns were greatest not only in incidence, but also in severity at about 1500 to 2000 meters. This again implies that only those who were slightly burned at distances closer to the center than 1500 meters survived. Nevertheless, a few illustrations are available of persons who have been exposed directly to the rays close to the point above which the bomb exploded.

There is evidence of the skin having attained a very high temperature for a very brief period. This is indicated in a severe burn by dehydration or even charring of the outermost parts of the skin with relatively little destruction or even edema of the underlying tissue (figures 29 and 30). Only those parts that faced the bomb were directly exposed to the rectilinear rays and consequently burned. This results from the relatively slight penetrating power of the damaging agent that has been mentioned. Thus, there are remarkable "profile burns" whose margins sharply delineate the surfaces that faced the explosion (figures 28, 34, and 35). The natural promontories of the body such as the nose, supra-orbital ridges, and jaw also effectively shaded parts of the face and neck (figures 26, 38, 39, and 49). Hats and clothes also offered partial, and often complete, protection as will be discussed. For the present it will suffice to inspect in the photographs the sharp outlines of the covered parts. In figures 26 and 33 are shown the effects of shading by the headgear and by the collar lines.

Parts Involved. As is to be expected from the statements just made, the exposed parts, especially the face and hands, were most frequently involved, the shoulders and deltoid regions often, and the abdomen and chest were relatively rarely burned. The hair, especially in women, usually protected the scalp, particularly in those closer than 2500 meters. Burns sometimes occurred beneath the clothes. The factors governing this will be discussed below.

The deepest burns were sometimes associated with damage to the cartilage of the ear with "cauliflower" deformity, as illustrated in figures 48 and 49. These patients were usually within 1500 meters. Bacterial infection of the substance of the auricle contributed to the chondritis in many instances.

Immediate Symptoms. The symptoms associated with the burns varied from case to case, but tended to follow a pattern. In those exposed at approximately 1000 meters, vesicles tended to appear more promptly than in those farther away. Thus in patient Namba (figure 44) and in patient Fuchimoto (figure 48) both pain and blisters were apparent within five minutes. In patient Sano (figure 49) the blisters appeared almost at once, but there was no pain until the next day.

At 1500 meters in patient Sasomoto (figure 31) pain appeared in two hours time, but blisters were not observed until the next day.

At 2000 meters in patient Nishizuki the pain did not appear until three hours had passed and blisters were not noted until after ten hours.

In some patients, however, as in Yanagida, there was vesiculation within ten minutes, even at 2000 meters.

Beyond 3000 meters many patients sustained only first degree burns,

whose symptoms and course resembled those of sunburn, except that erythema was usually more quickly observed.

There were exceptions to all the statements made in the preceding paragraph. The pain in most cases lasted only a few hours and thereafter the burns were almost painless.

Healing. Most survivors had second degree burns or second degree burns with small areas where the destruction of the skin was complete. The face, in contrast with the neck, where the skin is thinner, showed less scarring, since the epidermis is thicker here. Such an effect is illustrated in figures 28 and 48. Scarring with contractures about the joints was rare.

Since most burns were of second degree or less, healing was usually rapid and took place within four weeks.

All of the burns of second degree or worse became infected, and in some the bacterial agent destroyed portions of derma that had not been injured by the primary burns. This was especially true in the patients with radiation effects in whom healing was delayed. Some burns had not healed by the time the Commission left Hiroshima (1 December 1945), although the patients had long since recovered from leukopenia. In some instances there was the question of whether some direct effect of the gamma or associated radiation may have affected the healing.

Keloidal Changes. Overgrowth of scar tissue was observed frequently and sometimes was extreme in patients such as Akamatsu (figures 46 and 47). According to the Japanese physicians, however, the incidence of keloids was not greater than in burns of other causation in this race.

Treatment was primitive and the patients received little more than

dressings. Supportive therapy in the way of fluids and transfusions especially was deficient.

Pigmentation and Depigmentation. Among the striking features of the burns, were the changes in pigmentation. In those receiving minimal second degree burns the pigmentation was extreme, resembling that of a deep walnut stain over the entire surface of the burn. The pigmentation was especially deep and diffuse in patients who had been at a distance of approximately 2500 meters from the bomb, as had the group of villagers from Otake on their way over the Koi Bridge (See Section 10H). When this group of more than 300 people was foregathered in the assembly hall of the village school, the uniformity of the dark " mask of Hiroshima" was striking. Some of these people however, had suffered deeper destruction of the skin with resulting scarring which was probably produced by infection. A group of men who had been prisoners in the city jail (2300 meters) had the same deep chocolate-colored mask (figures 38, 41, 42; see also figure 26).

These burns were proceded by an intense erythema which within a few days became increasingly pigmented. Externally of the hyperpigmented area which has a sharp border is found a zone where there is even less pigment than in the normal skin with which it merges imperceptibly (figure 43; see also figures 26 and 27, at the lower borders of the burnt areas). This zone of depigmentation perhaps represents an area which some melanophores have abandoned to enter the hyperpigmented tissues. The pigment had begun to fade appreciably only in a few cases in three and one-half months.

In patients who had dark skins, the color of the burned zone was even darker than in the others. Furthermore, their natural hyperabundance

of pigment seemed to have given them more protection, since the skin shows less tendency towards depigmentation when they had been close to the bomb. Patient Takemoto, burned at 1400 meters (figures 36 and 37) is an excellent example. Contrariwise, in very light-skinned Japanese, pigmentation also tended to be faint (figure 45).

Depigmentation of the exposed skin occurred regularly at any distance less than 2000 meters (and occasionally at greater distance). It was not necessarily associated with scarring of the skin, but occurred in healed second degree burns. There was also histological evidence that loss of pigment in the basal layers can occur, even though the epithelium of the surface is not destroyed. At the margins of the depigmented zone is found a bronzed or narrow band of increased pigmentation, externally of which there is again a vaguely defined depigmented border which has been mentioned previously. Some typical examples are shown in figures 28, 31, 34 and 44. It is interesting to note that a pigmented nevus in one such zone retains its color (figure 44). In the same patient exposure to cold demonstrates that the erector pilorum muscles have not been damaged since there is goose flesh in the depigmented area to the same extent as in the completely undamaged skin.

Burns through clothing tended to be much less severe in some instances where the exposed skin suffered severe enough damage to become scarred. That portion of skin which was covered by cloth merely became depigmented (figure 31), or in some instances suffered even less severely as evidenced by diffuse hyperpigmentation (figures 35 and 55). This indicates that the rays producing the burns can penetrate cloth to a certain extent.

Etiology of the burns. Certain feature of the burns suggest the action of specific wave lengths, perhaps in the ultraviolet. The intensity of the pigmentation in the very mild second degree burns as seen at 2500 meters, and the sharply demarcated and extreme depigmentation without destruction of the skin closer to the bomb was certainly unusual merely as a result of thermal injury. It must be remembered that a relatively small quantity of air intervened between the patients and the bomb, in comparison with the entire atmosphere and stratosphere which filter out much of the ultra-violet of the sun. The diverse effects upon the skin of specific bands in the ultra-violet have recently been pointed out by Blum and Terus.* Much is still to be learned concerning the action of high intensities of ultra-violet. The complexity of the sun's spectrum and the influences of filtration occasioned by elevation of the sun above the horizon have been summarized by Blum.** It is most unlikely that gamma rays were responsible for the sharply outlined pigmentary phenomena that have been described, since clothing would be no barrier to their action.

Protective Effect of Clothing. Clothing exerted a protective effect depending on a series of interrelated factors that include, (1) distance from the bomb, (2) color, (3) tightness of the clothing, (4) thickness and number of layers. These factors will be discussed seriatim.

1. Distance: It can be stated in general terms that burns beneath clothing were rare beyond 2300 meters. Of importance also is the fact that

*Blum, H. F. and Terus, W. S.: Studies of Sunburn. Inhibition of Erythema by Larger Doses of Ultraviolet Radiation. U. S. Naval Medical Research Institute. Research Project X-108. Report No. 3
**Blum, H. F.: The Physiological Effects of Sunlight on Man. Physiol. Rev. 25: 483-530, 1945.

a khaki uniform-coat and shirt worn together were protective beyond 1500 meters.

Closer to the bomb clothes were of little protection (figure 29). Particularly when of dark color, clothes in some instance actually caught fire so that flames had to be beaten out with the hands. This was proved beyond peradventure for in some circumstances there were no adjacent objects from which fire could have spread to the clothes. Some clothes smoldered and charred, and others were merely scorched. All of these effects on the clothing were observed as far out as 2500 meters. When the clothes caught fire the burns were truly flame burns and were among the most severe that were encountered by the Commission. In general, however, as has been discussed above, burns beneath the clothing were less severe than upon the exposed parts. It is possible for "flash burns" to occur beneath entirely intact clothing (e.g., patient Maebara, Case No. O-8388-P).

2. Color and Shade. The darkest shades absorbed very much more heat. The effect of selective absorption at 2300 meters is strikingly shown in the case of Japanese rice paper, where the black print had been completely burned out (figure 50). Similar effects occurred between 1500 and 2000 meters, also in the case of clothes. The relation seemed to be to darkness of shade, rather than to color.

At 1600 meters in the case of a white rayon shirt with a pattern of dark blue polka dots 2 millimeters in diameter and one centimeter apart, the polka dots were burned in the line of the rays. Other polka dots were partly scorched (figure 51). The difference in intensity of effect probably bore relation to the angle of incidence of the rays. This patient sustained burns of the chest beneath this garment.

At 1700 meters, in a rayon shirt with a pattern of blue-black stripes one millimeter wide alternating with light gray stripes approximately twice that width, the darker material was deeply scorched where the folds of the garment had caught the rays on the side away from the bomb (see figure 52). On the proximal side some portions of the white material were also charred and there were third degree burns of the skin of the thorax.

Extremely interesting is the effect upon cotton cloth with a flowered pattern on a light pink background. The flowers were dark red roses with leaves of varying shades of green. Some of the flowers were entirely burned out, others showed scorching only of the darker portions of the leaves and petals (figure 53 and 54). The burns of the patient's left arm at first corresponded with the burnt out flowers, but they had ultimately become confluent on account of infection, and by the time she was seen by the Commission, healing was complete. In one patient observed and photographed by the Japanese medical officers of the Tokyo First Military Hospital, the pattern of the darker stripes was reproduced in burns of the skin, as illustrated in figures 55 and 56. Unfortunately, the distance is not recorded in this case.

3. <u>Tightness</u>. Where the clothing was more tightly stretched, burns were much more likely to occur. This is well brought out by a study of figures 57 and 58. Over the scapular and deltoid regions of a patient (who was at 1200 meters), the burns bore relation to the charring of the kimono, but where the sleeve was baggy, as in relation to the lower part of the upper arm, there were no burns of the skin, although charring of the cloth had occurred. Other examples showing particular effect on the deltoid region are shown in figures

28 and 42, on the scapula in figure 31, and on the pectoral region in figure 40.

4. Thickness and Number of Layers. The effect of the number of layers is shown in figure 32. Below the V-line of the neck produced by the open shirt, the skin is intact where the collar is folded over, but toward the right the wall of the chest is burned, in part to the third degree, through the single layer of cloth.

The protective effect of the seams, where the sleeves join the body of the garment and the cloth is in a thick roll, is strikingly shown in figures 46 and 58, where also the straps of the undergarments supplied an additional, and adequate, layer of protective material.

Summary: "Flash burns" in Hiroshima occurred up to a distance of 4500 meters (2 1/2 miles) but rarely was there vesiculation of the skin or necessity for treatment of patients who had been beyond 3300 meters. The burns were of "profile" type, since only surfaces directly in the rectilinear path of the rays were affected. There is some evidence that specific portions of the spectrum accounted for the peculiarities of pigmentation and depigmentation that were observed. There was histological evidence that the latter could occur without destruction of the squamous epithelium of the surface. Depigmentation was prominent in patients close to the center, but there was a marginal zone of pigmentation. Pigmentation was prominent beyond 2000 meters and represented the minimal residual effect of the rays. Clothes, particularly when light in color and several layers in thickness and when loosely worn, offered some measure of protection, especially beyond 2300 meters.

C. RADIATION INJURY

<u>Nature of the Injurious Agent</u>. During and immediately after the nuclear fission by which the atomic bomb is distinguished from all others, there were produced gamma rays and neutrons, as well as other radiation which could not have reached the surface of the earth. Some of the neutrons gave rise during their passage through the gases of the atmosphere to additional gamma rays. Upon striking the surface of the earth artificial radioactivity was set up. Others encountered the human target in their paths, but probably not beyond 1000 meters from the point above which the bomb exploded. Some of the fission products were carried with the prevailing winds to the southwestern parts of the city and its environs where, near the villages of Takasu and Furue, they were deposited by a rainstorm that fell some three hours after the bombing. Thus there are four possible sources of damage to the body by radioactivity.

1. By deposited fission products. Their existence was demonstrated chemically, but they were deposited in too low a concentration to do more than perhaps temporarily depress the white count in some individuals. The subject is discussed in Section 2 and in the appendix of section 4H (Reference 1). The well water at Takasu was tested by Professor Shinohara on 2 November 1945, and was found to be completely inactive.

2. By induced radioactivity beneath the bomb. This was of an order so low as to be ineffectual in damaging human beings who came to work near the center. This was attested by studies of the Ishizuka Unit as presented in Appendix 4H (Reference 1).

3. By gamma rays.

4. By neutrons striking the body directly.

The last two were the important factors in producing the radiation effects. It is not the purpose of this section to discuss the energies concerned nor the dosage received by the various tissues, but merely to present in an objective manner the clinical observations.

In this and succeeding paragraphs appears an account of the most important signs and symptoms of radiation effect, together with a statement of the commonest clinical syndromes observed. The interrelations of the various symptoms in their relation to shielding and distance, is the subject of the statistical analysis in Section 9.

Incidence and Mortality. Before discussing the incidence, the criteria of "radiation effect" must be defined. Clinical criteria based chiefly on the presence of epilation or purpura were employed for reasons that are discussed in Section 9. In that section are contemplated survivors who lived for longer than twenty days after the bombing. The clinical criteria mentioned do not usually appear for at least two weeks.

Had it been possible to determine the leukocyte counts in an adequate sample of the population at close intervals of time after the bombing "radiation effects" based on the criterion of leukopenia would probably have been recognized in a higher percentage of people and at greater distances from the center. The incidence of radiation effect is seen to fall off very sharply beyond 1250 meters. The shielding effect of heavy buildings is indicated in Section 9 and more specifically, in Sections 10H and 11H.

The mortality from radiation effects is known for several specific conditions: (1), At the Bankers' Club (250 meters) there was only one survivor among nine who had minor or moderately severe injuries and no burns; all had clinical evidence of severe radiation effects as discussed below. Among fourteen others there was only one who survived and most of these patients had second degree burns of the face or extremities, or both. The average shielding effects of the walls and ceiling of this building are equivalent to from 65 to 241 inches of water (Section 11H).

At 1000 meters men protected from burns by interposed Japanese buildings and otherwise uninjured, show a mortality of 58.5% (Section 10H, p. 17, Otake Group). In contrast with this is the well established observation that deaths from radiation effects in concrete buildings beyond 1000 meters are extremely rare in Hiroshima.

These specific points of reference are the only ones available for Hiroshima. They do not supply information as to how many individuals died from radiation effects, but merely indicate the mortality from radiation under the conditions specified, if there had been no other injuries. The effects of the radiation, however, doubtless contributed to the 94.7% mortality of individuals completely unshielded at 1000 meters (See Section 10H), and to that of other persons within 1500 meters who had infected traumatic or thermal lesions.

The time of death from radiation effect depends on exposure. Thus at the Bankers' Club the peak came between the ninth and tenth day after the bombing (table 3). The personnel at the Second Military Hospital (800 - 900 ...

Table 3

Hiroshima - Mortality Statistics of Personnel

at Bankers' Club (250 meters)

Group*	Day and Date												
	11 Aug (6)	12 Aug (7)	13 Aug (8)	14 Aug (9)	15 Aug (10)	16 Aug (11)	17 Aug (12)	18 Aug (13)	19 Aug (14)	20 Aug (15)	21 Aug (16)	22 Aug (17)	23 Aug (18)
Slight or no burns		1	1	1	2		1		1				1
Burns	2	2	1	5	2								1
All	2	3	2	6	4	0	1	0	1	0	0	0	2

*One survivor in each group.

Table ** 4

Hiroshima - Mortality Statistics of Personnel

At Hiroshima Second Military Hospital (800-900 meters)

Day and Date	6 Aug (1)	7 - 10 Aug (2-5)	11 - 20 Aug (6-15)	21 - 30 Aug (16-25)	31 Aug (26-36)	11 - 20 Sept (37-46)	21 - 30 Sept (47-56)	1 - 10 Oct (57-66)
No. of Deaths	61	12	46	65	33	5	1	1

** From Ref. (1), Appendix 4H

meters) showed two peaks in the mortality curve, one on the day of the bombing and another in the last ten days of August(16th to 25th days). The first can be ascribed largely to burns; the second peak is largely accounted for by radiation injury (table 4).

Clinical Observations. The pathogenesis of the signs and symptoms will first be considered and then will follow an outline of the commonest clinical syndromes.

Radiation effects were manifest by direct action on the skin, oral and gastrointestinal mucousmembrane, gonads, lymphoid and hematopoietic tissues. The last mentioned effect resulted in the appearance of the same lesions of the skin, mucous membranes and viscera that are seen in agranulocytosis or in aplastic anemia of any cause.

1. The Skin. Epilation was frequently observed among persons who had been close to the bomb and who survived for more than two weeks. At 500 meters its incidence was approximately 75%. It fell off sharply beyond 1250 meters, Section 9, figure 6H. It was almost constantly present in patients coming to autopsy between the third and sixth weeks (Section 8, table 15a) 86% of such individuals had epilation of the scalp. The effect of shielding by heavy buildings is striking, as shown in figure 10H, of Section 9.

The time of onset of the epilation reached a very sharp peak, between thirteen and fourteen days after the bombing. The peak for males and females coincided. It is likely that some errors were made in diagnosis, since hair is always being lost and the people too easily found in themselves symptoms that were common in others. In the true epilation, the hair

rather suddenly began to fall out in bunches upon combing or gentle plucking, or it was found in considerable quantities on the pillow in the morning. This process continued for one or two weeks and then ceased. In most cases at the end of this time the distribution was that of ordinary baldness in both sexes, involving first the frontal and then the parietal and occipital regions and sparing the temporal regions and the scruff of the neck (figure 68). In some, however, even the generally more resistant parts were epilated, but in such persons there remained scattered, short, fine, downy hairs all over the head (figures 61, 64, and 66).

The eyebrows (figures 69 and 64) and even more so the eyelashes and beard, were relatively resistant to plucking. In patients who came to autopsy, 48 had epilation of the head, 8 of the axilla, 6 of the pubic regions, 4 of the eyebrows and 2 of the beard.

Complete epilation is not necessarily correlated with a bad prognosis; on the other hand, 14% of individuals who died of radiation effect at approximately the fourth week, had no epilation of the scalp.

Even in severe cases, the hair had begun to return by the middle of October, from eight to ten weeks after the bombing, and recovery was well under way a month thereafter (figures 64 to 67). Some of the new hairs were downy, but others were of the usual robustness. The appearance of the follicles was identical at each stage with that of hair in the usual cycle of loss and replacement. In the radiated patients, however, vast numbers of follicles were involved all at one time. In none of the survivors known to the Commission was the epilation permanent.

The existence of other direct radiation injury to the skin was not proved histologically beyond peradventure. This subject is discussed in Section 8. Such vesicular lesions as were observed in Nagasaki, are not described in Hiroshima, although pustular and ulcerative lesions occurred.

2. Oral and Gastrointestinal Tissues. In the succeeding paragraphs only symptoms considered to be the direct result of radiation are reviewed. The severe lesions in these organs and the accompanying signs and symptoms which were the result of aplastic anemic are discussed later.

In the section of pathology (8) lesions are described in the tongue, larynx, esophagus and intestines, which are probably the direct result of the action of radiation of such penetrating power as to affect these deep mucous membranes relatively more than the skin. The beginnings of ulceration with no tissue response except edema were seen in the esophagus and in the intestines. Since the autopsy material is so scanty the incidence of such lesions is unknown. Symptoms of severe pain in the throat and gums occurred relatively early.

In many patients who were close to the point of explosion, severe nausea and vomiting occurred from thirty minutes to three hours after the bombing, sometimes, however, not until the next day. Thirty two and one-tenths per-cent of individuals within the first 1000 meters, and 23.2% who were between 1100 and 1500 meters, suffered from vomiting on the day of the bombing. The incidence fell sharply to 6.6% in the third ring zone to attain a level of zero in the seventh ring zone. The mechanism and underlying lesions are

difficult to determine. Nausea and vomiting are common after therapeutic X-irradiation.

Diarrhea, sometimes sanguineous, occurred within the first few days in some patients. In the severe cases it was probably associated with the changes in the mucous membrane of the gastrointestinal tract, which have been described. Diarrheal diseases, however, may spread immensely in populations disorganized and crowded as a result of destruction of a city. Furthermore, the incidence of diarrhea in populations near Hiroshima not directly affected by the bomb is normally high.

3. Gonads. Histologically radiation effects on the testes were discernible as early as the fourth day and they were profound in all fatal cases who had been within 1500 meters of the bomb. It was obviously of interest to study the sperm counts in survivors. Standard methods were employed as outlined in Section 4H. The results are as follows: It is apparent that only three of the twenty-three patients who had been within 1500 meters, had a count in excess of 40,000 (the lower limit of normal); of thirty-nine men who had been beyond 2.0 kilometers, thirteen had counts below 40,000 per cubic millimeter. In general, patients with low counts had a normal proportion of active spermatozoa, but in eight of twenty-five men whose sperm counts were lower than 10,000 per cc, more than one-half of the spermatozoa were judged to be actively motile (table 6). It remains to be determined whether in the survivors there will be an increase in the count as dietary conditions improve. According to Macomber and Sanders*, it is unusual for pregnancy to occur if the

*Macomber, D., and Sanders, M. B., The Spermatozoa Count. Its value in the Diagnosis, Prognosis and Treatment of Sterility. New England J. Med., 200: 981-983, 1929.

Table 5

Hiroshima

Counts of Spermatozoa

Distance	Number of Spermatozoa per cc (millions)		
	0-10	11-40	41 +
0 - 1.0	4	4	1
1.1 - 1.5	7	5	2
1.6 - 2.0	8	3	6
2.1 +	5	8	26

Table 6

Hiroshima

Correlation of Number and Percentage of Motile Spermatozoa

% of Motile Spermatozoa	Number of Spermatozoa per cc. (millions)		
	0-10	11-40	41 +
0%	12	0	0
1-25%	5	5	0
26-50%	4	13	7
51%	4	3	14

spermatozoa count is below 40,000. Many of the patients complained of a loss of libido, or even loss of potency following the bombing, but this may have been associated with acute or chronic illness.

Histologically the ovaries showed less striking changes than the testes. The incidence of amenorrhea in Hiroshima as shown in table 15H of Section 9, increases the closer the patients are to the center. During the war years in Japan, there was a high incidence of amenorrhea, as indicated in table 7. These background data are supplied by Doctor Mitani and Doctor Matsumoto. The studies were carried out in Tokyo where the incidence of secondary amenorrhea of three or more months duration is defined as amenorrhea of unknown cause in patients who had previously menstruated regularly and who were not pregnant. The marked increase after December 1943 is shown in table 8, where the month by month incidence is presented. Among the factors concerned in this rise, according to the Japanese gynecologists were: (1) malnutrition; (2) overwork; (3) anxiety associated with the bombing. In November 1944 the incidence among 360 nurses of the Tokyo Imperial University Hospital was similar, 13.3%.

Endometrium was obtained from thirty patients in the outpatient department. All of these had thin endometrium in the early proliferative phase. There was one case of carcinoma of the body of the uterus. Without treatment 60% of the patients in the clinic group recovered spontaneously.

Twenty-five patients were studied and endometrial biopsies were obtained at Hiroshima by Doctor Mitani and Doctor Iwai. These specimens, together with complete records of the menstrual histories of the patients, were examined by the Joint Commission. All specimens showed endometrium in the proliferative

Table 7

Incidence of "Functional Amenorrhea"

Tokyo Imperial University Gyn. Outpatient Clinic

Year	Number of Outpatients	Incidence of Amenorrhea	
		Number	Percent
1932	4734	205	4.3
1942	3937	150	3.8
1943	3851	188	4.9
1944	2637	317	12.0

Table 8

Incidence of "Functional Amenorrhea"

Tokyo Imperial University Gyn. Outpatient Clinic

Month	Year	
	1943	1944
January	4.6%	7.6%
February	5.7%	10.5%
March	4.7%	10.3%
April	2.8%	9.4%
May	3.1%	13.5%
June	4.3%	9.5%
July	2.9%	11.7%
August	5.4%	9.6%
September	3.9%	13.0%
October	4.9%	11.7%
November	6.1%	13.3%
December	10.0%	9.1%

phase, with no evidence of corpus luteum effect.

4. <u>Consequences of Damage to the Hematopoietic System.</u> In persons exposed to radiation, the lymphoid and hematopoietic tissues underwent rapid necrobiosis at a rate and degree of completeness which is detailed in Sections 6, 7, 8. A striking leukopenia was observed in the most heavily exposed patients within the first week. The first recorded counts are five days after the bombing and at this time counts as low as 150 white blood cells per cubic millimeter are recorded. In specimens of vertebral marrow obtained ten days after the bombing there is almost total loss of myelopoietic tissue, as illustrated in Section 8, figure 13.

It now remains to discuss the pathogenesis and clinical manifestations of the lesions associated with this process. They consist of hemorrhage and necrosis, especially of tissues in continuity with the bacterially contaminated surfaces of the body. The lesions are prominent in the skin and the oropharyngeal and intestinal and respiratory systems.

The hemorrhagic aspects will be considered first. Involved in this are: (a) a platelet factor; (b) dietary factors; (c) infection factors; and (d) capillary fragility factors.

(a) The Platelet Factor: In fourteen fatal cases dying between the fourth to seventh weeks in whom platelet counts are available, only two were above 60,000 per cubic millimeter; one was between 68,000 and 69,000 and another between 54,000 and 55,000. One count was 34,000 and all the rest below 25,000; three were below 10,000. In all of these patients the bleeding time was increased, in some to as long as 46 minutes (figures 59 and 60). The

clotting time was also slightly prolonged during the acute phases of the illnesses. These findings are discussed in detail in Section 6.

(b) Dietary Factors. Vitamin C levels were determined by the Kyoto Research Group (See ref. #2, appendix 4H), employing the dichlorphenol-indophenol method. Accurate prothrombin times were not available for patients during the acute stages. Vitamin C levels were low (table 9).

(c) Infection Factor. No specific bacteriologic data was obtained, but there was evidence of bacteremia in some of the fatal cases in whom streptococci or bacilli were found in freshly fixed tissues derived from the bone marrow (figures 82, 83, and 84, in Section 8). There is evidence of at least localized infections in all of the severe cases of radiation injury. The association of bacterial infection, and hemorrhage is well known but not well understood.

(d) Capillary Fragility. The capillary resistance was tested by Borbély's negative pressure method. It was found to be diminished in some individuals at the fifth week and at that time seemed to run parallel to the white blood count. Individuals surviving to the seventh week manifested no evidence of decreased resistance. The Rumpell-Leede test was usually negative.

Characteristic of the Hemorrhagic Phenomena. For convenience these will be referred to as "purpura." In the skin, purpura was almost always manifested in patients dying from the third to the sixth week, inclusive (table 15a, Section 8). Its incidence at various distances from the center ran almost exactly to that of epilation and fell off sharply after 1250 meters

Table 9

Hiroshima

Plasma Vitamin C Levels*

Case No.	Age	Date	RBC	WBC	Vitamin C mg/100 cc
13	32	8 Sept	2.13	1750	0.03
49	18	5 Sept	2.65	2000	0.11
52	29	"	2.87	2000	0.33
53	37	"	3.12	1750	0.33
54	24	"	2.83	4000	0.89
56	23	"	2.82	5800	0.92
57	35	"	3.16	3100	0.52
62	29	6 Sept	2.89	6200	0.52
64	19	15 Sept	3.19	4150	0.57
68	37	7 Sept	3.04	1450	0.00

Normal values for Japanese = 0.8 - 2.4 mg/100 cc

*Performed by Research Commission of the Imperial University of Kyoto. Exact details of the method are not given.

(table 14H, section 9). According to Japanese observers purpuric spots tended to appear at about the same time or one to two days later than fever. Their onset is at a peak between the sixteenth and twenty-second day, some five days later than the peak of epilation. Purpura is rare before the end of the second week. The largest number of patients is involved at about the fourth week following the bombing. The hemorrhages are most prominent in the upper half of the body and involve particularly the head, face, flexor surfaces of the upper arms and the anterior aspects of the thorax (figures 59 and 60). Associated with their onset, there is an increased tendency to bleed from lacerations, fractures and burns. After the onset of the purpura of the skin, hemorrhages were also prominent in the gigivae, and from the rectum, nose, urinary tract and respiratory passages, in that order of frequency. Epistaxis was often sudden in onset and difficult to control. At necropsy, petechiae were found in the pelvis of the kidney with great frequency, but in the parenchyma they occurred only in 11% of patients dying during the time when the hemorrhagic manifestations were at their height (See table 24, section 8). In the gingivae and intestinal tract hemorrhage was usually associated with obvious infection. Petechiae occasionally occurred in the conjunctiva. They were present also, either in the acute or organized form, in eight of thirty-two patients with radiation effect who had fundiscopic examination.

In association with the leukopenia and anemia there occur necrotizing lesions entirely analogous to those seen in agranulocytosis. In many of these patients there is some question as to whether the earliest changes may not in fact have been the result of direct action of the ionizing radiation. Evidence for this is present in Group I (patients dying before the 15th day) in the section on Pathology (8). This is suggested clinically by the onset of gingivitis and stomatitis in some patients before the end of the second week. These lesions, however, do not usually appear until the third and fourth weeks. In later stages, changes suggestive of radiation effect may be obscured by widespread necrosis of the mucous membrane.

Whatever the mechanism, the lesions in the patients with profound leukopenia show necrosis, often with massive bacterial infiltration upon the surface and in the immediately underlying tissues, and edema--with few, if any, polymorphonuclear leukocytes. Hemorrhages are usually present and may be massive, for reasons already discussed. The onset of the cutaneous and oropharyngeal lesion is usually at about the same time as the purpura--between the 17th and 23d days. Ulcerative and hemorrhagic lesions of the skin may occur at the site of old lacerations or by infection of hemorrhagic zones. The multiple lacerations associated with penetrating fragments of glass have already been described. Even when partly healed, they may, in patients with leukopenia, suddenly become infected and hemorrhagic. Pustular and vesicular lesions also occur in some patients, especially in the fatal cases (Section 8, table 15A). What

relation these have to primary damage to the skin by ionizing radiation is not known but is discussed in the section on Pathology (8). Any mucous membrane may be involved. Lesions of this type have been grouped together as "oropharyngeal lesions" and their incidence and interrelations are discussed in section 9.

The lips may be the seat of a cheilitis with edema and superficial ulceration and sometimes with cellulitis. Gingivitis is characterized at first by redness and swelling. In some patients there is further swelling associated with hemorrhage and in a few, especially the fatal cases, there is actual necrosis with ulceration of the gums. The incisorial regions are most commonly involved (figure 61). The teeth are rarely loosened. Healing occurs sluggishly by re-epithelization, but the gums remain red and swollen for long periods of time and there is usually a tendency for superficial zones of ulceration and scarring to remain upon the buccal and gingival membranes (figure 62). Necrosis and hemorrhage of the anterior portions of the tongue occurred in two fatal cases (figure 63; see also figure 125 in Section 8). There may also be a stomatitis resembling the cheilitis. Both the lingual and faucial tonsils may be involved. The lesion is usually associated with severe pharyngeal pain, trismus and pain on swallowing. Despite total necrosis, the tonsils were not always enlarged. In patients who recovered the lesions in the tonsils tended to persist after the purpuric manifestations and fever had subsided.

The lungs were frequently involved in a necrotizing and hemorrhagic process--by continuous necrosis of the mucous membrane of the bronchi and

bronchioles, finally with involvement of the parenchyma. Histologically hemorrhage is a prominent feature of the lesion but clinically hemoptyses are rare. There are few recorded data concerning the clinical manifestations of these lesions.

Many patients had diarrhea during life in association with necrotizing and hemorrhagic lesions of the intestines. These were most frequently situated on the ileo-cecal valve. At the Ujina Hospital approximately 15 per cent of the individuals with radiation effect had guaiac positive stools.

The remarks just concluded concern the injurious factors in the atomic bomb and, crudely, the mechanism of their effect. There now remains to consider what clinical grouping of the cases may be made. Emphasis will, as a matter of course, be placed on the radiation effects. The clinical types fall easily into 4 groups:

Group I. Patients dying in the 1st and 2d weeks.

Group II. Patients suffering severe symptoms, or dying in the 3d, 4th, 5th and 6th weeks.

Group III. Patients dying after the 6th week.

Group IV. Mild cases.

The fatal cases in Groups I, II and III have the same designation and definition in Section 8, where the Pathology is discussed.

Among the conditions that determine into which group a given case will fall are:

1. Factors of exposure, as determined by distance from the bomb and by shelter.

2. Factors of individual susceptibility.

3. Complicating factors such as loss of blood, or the coexistence of burns.

4. Factors of therapy. The meagreness of the therapy applied to most of the patients under consideration has already been stressed.

The various groups will now be considered in turn.

Group I: Patients dying within the first two weeks.

In this group there is histological evidence of radiation effects upon the skin, gastrointestinal tract, lymphoid tissue, bone marrow, and gonads but these have not become clinically manifest. There is no epilation and usually no purpura. Patients complain of nausea and vomiting on the first day of the bombing followed by anorexia, malaise, severe diarrhea, thirst, and fever. Death ensues in delirium within the first two weeks. Leukopenia is found in many of these cases by the fifth day and doubtless occurs sooner.

First hand information concerning some of the features of the early cases is available from the records of the Iwakuni Hospital. Temperature charts were kept and hematological examinations were performed. Details of the clinical histories, however, are scanty, as there is record only of the most important signs and symptoms. Thus nausea and vomiting on the first day, which was common among those with radiation effect who survived for 3 weeks or more, was rarely recorded. This probably indicates either that the questions were not asked, or that the patients were too ill to respond.

The patients under consideration were all in the "Bankers' Club"

building, which is situated 250 meters from the point above which the bomb exploded. A study of the building from the point of view of filtration factors is presented in Section 11H. Of 23 individuals in this building who were admitted to the Iwakuni Naval Hospital, all but 2 had died by the 23d of August. The case history of one of the survivors, Terachi, a telephone operator who supplied information concerning the others, is presented in Group IV of this section.

It is considered desirable to consider the symptoms of those who had no burns, or minor burns no greater than the first degree. There are 8 such in addition to the survivor, Terachi, who fall into this category. All but one of the fatal cases had diarrhea, which was of watery type. The number of stools per day was as high as 28 in one case and ranged from 2 to 10 in the others. None of the patients dying in the first week had evidence of epilation. A few scattered petechiae were noted on the chest in one case. It was of note that one had stomatitis and pharyngitis and another gingivitis and pharyngitis.

The temperature records in all of these patients were remarkably similar. Usually, between the fifth and seventh days, but sometimes as early as the third, there was a steplike rise of temperature usually continuing to the day of death. Four charts are presented with the counts and numbers of stools recorded for the appropriate day together with the clinical histories, which include all available information. There is remarkable similarity not only in the temperature curve but in the other clinical manifestations. These cases, moreover, are representative of the group as

a whole.

The white blood cells were first recorded as early as 11 August, but the first examinations were usually performed on the following day. There is not one among the 7 fatal cases in whom data are available where the count was higher than 1500. In 5 of the 7 it was below 500. There was also a striking anemia in these patients by the end of the first week, despite the fact that in most of them blood had been lost in slight, if any, quantity. The RBC varied from 1.4 to 4.2. There was a disproportionately low hemoglobin. It was not greater than 54 in any patient; in one it was 25, and in the others it ranged between 40 and 50 per cent.

The symptoms among the 14 patients with burns of second degree or greater, usually were very similar. One patient, who lived to the 23d Aug, developed severe epilation on the 20th. The one survivor, Kozuka, Case No. H-10633-1, was discharged on the 24th. He, too, developed epilation before his release from the hospital. His first count had been 250 WBC per cmm on 12 August but had risen to 3,600 by the 19th. Scattered purpuric spots were present in one patient who died on the 11th. There was only one patient who had stomatitis when admitted on 9 August and pharyngitis which began on the 12th. He died on 14 August. Another who died on the 14th also had stomatitis. The dates of death for both groups are shown in table 3 earlier in this section.

An account of the symptoms in 181 cases terminating fatally before the end of the 11th day and including patients with severe burns and injuries is given in the report of the Japanese Army Medical School (Appendix 4H,

Reference No. 1): "Of a total of 181 cases, 159 had fever, 85 had diarrhea including 10 cases with bloody stools, 22 had a hemorrhagic tendency including those with bloody stools, 2 had petechiae, 2 with epistaxis and one with gingival bleeding." The bloody diarrhea resembled that of dysentery but bacteriologic examinations performed at the Ninoshima Hospital were negative.

Death in these patients was associated with the destruction of tissue, as demonstrated in Section 8, and probably also with bacterial infection. In animals dying soon after irradiation, Lawrence & Tennant* considered the former factor to be the more important.

*Lawrence, J. H., & Tennant, R.: The Comparative Effects of Neutrons and X-Rays of the Whole Body. Jour. Exp. Med., 66: 667-688, 1937.

Case Report: Nakane, Eiichi

Case No. H-6019-U

This 31 year old petty officer of the Japanese Navy was admitted to the Iwakani Hospital on the 9th of August. He was in the Bankers' Club (250 meters) at the time of the bombing and suffered first degree burns of the face, neck, and chest, contusions of the nose and right hand and an abrasion of the left elbow. On the 12th of August he began to complain of abdominal pain, nausea, anorexia and dizziness and a diarrhea began, which reached a frequency of ten on the following two days. At the same time his temperature began to rise and continued upwards to reach a level of 39.4° C at the time of death on 15 August 1945. (See temperature record). On that day a few petechiae appeared on the chest.

"Autohemotherapy" was administered.

Laboratory Data:

Blood	RBC	Sahli Hgb	WBC*	Ly.	M.	Stab.	Seg.	Eo.	Nuc. RBC
12 Aug	4.69	50	150	30	4	8	50	4	4
13 Aug	4.20	49	200						

*"Giant neutrophiles" present (See Section 6).

Urine (13 Aug): Alb. and Sugar Neg. 2-3 WBC and 3-4 RBC/HPF

Stool (14 Aug): Neg. for typhoid or dysentery.

Case Report: Ootsuka, Shigeru

Case No. H-10622-I

This 27 year old paymaster of the Japanese Navy was on the first floor of the Bankers' Club (250 meters) at the time of the bombing. The only

injuries were contusions of the head, face, and neck, and abrasions of the hands. He was admitted to the Iwakuni Hospital on 9 August 1945. He complained of a cough which was productive of sputum, and of anorexia and diarrhea. At the time of admission his temperature was 38.8° C. For the next two days it was just slightly above normal, but thereafter it rose steadily to levels as high as 40.6° C. towards the end. On the 19th of August he had a hemoptysis and he expired on the next day. He also suffered from stomatitis whose date of onset is unstated.

Four transfusions were given of 100 cc each. He had a striking leukopenia and anemia.

Laboratory Data:

Blood	RBC	Sahli Hgb	WBC
12 Aug			400
13 Aug	1.35	44	125
14 Aug			125
15 Aug			100
17 Aug			82
18 Aug			113

Urine (12 Aug): Alb. and Sugar Neg. 1-2 RBC and 3-5 WBC/HPF

Case Report: Kumano, Iwao

Case No. H-10635-I

This 22 year old seaman who was admitted on the 9th of August sustained contusions of the head and face at the time of the bombing. He was in the Bankers' Club building at the time. Following the bombing, he complained of

dizziness. Nausea and vomiting occurred beginning with the 12th of August and at the same time a sudden rise in temperature occurred. This continued, reaching a level of 40.2° C on the day of death, the 14th of August. There was diarrhea on the last two days. "Autohemotherapy" was administered.

Laboratory Data:

Blood	RBC	Hgb	WHC	Ly.	M.	Seg.*
12 Aug	2.82	40	300	1	1	18 (20 cells counted)

*Giant neutrophiles present.

Urine (13 Aug): Alb. and Sugar Neg. 2-3 WBC/HPF

Stool culture (14 Aug): Neg.

Case Report: Kurauchi, Yoshiaki

Case No. H-10645-I

The patient, a 31 year old seaman, was at the Bankers' Club building at the time of the bombing, and received contusions of the face and left forearm, together with first degree burns of the face and neck. He was admitted to the Iwakuni Hospital on the 9th of August. At this time he had malaise and anorexia and diarrheal stools, but they did not become frequent until the 13th. Their number reached 28 two days later. On the 12th began a fever which rose continuously, to attain levels as high as 40°C within the next two days. Pharyngitis appeared on the 14th of August and there was also a stomatitis whose date of onset is not stated. His blood pressure was 90/45 on August 13.

Laboratory Data:

Blood	**RBC**	**Hgb.**	**WBC**	**Ly.**	**M.**	**Juv.**	**Stab.**	**Seg.**	**E.**	**B.**
12 Aug	4.20	45	400	14	2	9	12	68	0	1
15 Aug	4.30	60	250							
16 Aug			200							
17 Aug			270							

Bone Marrow (Date not stated): Stab cells: 1. Ly.: 29. M.: 1. Monoblast: 1. Reticulum cells: 11. Plasma cells: 7.

Urine (13 Aug): Alb. and Sugar. Neg. 2-3 WBC/HPF

Stool Culture (13 Aug): Neg.

Group II: Patients dying during the 3d, 4th, 5th, and 6th weeks, or surviving severe symptoms.

In this group the anatomical and clinical results of the radiation attain their acme. Epilation is prominent as is the hypoplasia or failure of maturation of the bone marrow. The hemorrhagic and necrotizing lesions which are consequent upon the latter are entirely comparable to those seen in aplastic anemia and agranulocytosis. Petechiae of the skin are almost always present. There are necrotizing lesions of the gums, and respiratory and gastrointestinal tracts. The sequence of symptoms is somewhat as follows: In a typical severe case the first evidence of the disease is nausea and vomiting on the day of the bombing, followed by a feeling of malaise. Then there are no other additional symptoms except for epilation which begins 2 weeks after the bombing. Usually, approximately 5 days after this, accompanied by increasing malaise, there is a step-like rise in temperature similar to that seen in Group I. At approximately the same time pharyngeal pain may appear or this may come somewhat later. Gingivitis and petechiae become manifest on the same day or within a few days after onset of the febrile episode. Sanguineous diarrhea is frequently a prominent symptom at the height of the disease and may appear very early. Stool cultures made from 160 of these patients at the 30th of August were all negative. The leukocytes and platelets reach very low levels at the time of the fever and there may be a severe anemia. The patient usually dies within one or two weeks after the onset of the fever.

The ~~mechanism of death in~~ these patients who had widespread infected

necrotic and hemorrhagic lesions is not difficult to understand. The presence of bacteria in the well-fixed bone marrows of two patients autopsied immediately after death (figs. 13, 82, 83, 89 in section 8) indicates the massive bacteremias that can occur. Cultures of blood were made in 19 patients as recorded in the Japanese Army Medical School report with the following results: Strep. hemolyticus 1, Strep viridans 1, B. coli 1, Gram-positive diplococcus 1. This information is scanty, but indicates that blood cultures are frequently positive in these patients.

Some patients exhibiting all or several of the symptoms of purpura, gingivitis, and severe or even necrotizing pharyngitis survive after a febrile period. In relation to defervescence non-necrotic pharyngitis ceases before, petechiae before or during, and gingivitis usually after the end of the febrile period. Recovery is associated with an increase in the circulating leucocytes and platelets. Many of these patients remain in an anemic and generally debilitated condition for long periods. In survivors the red count tends to fall slowly for some weeks after the end of the severe illness. It is interesting to note that the leucocytes are at their lowest in the fourth week in those surviving more than 20 days. In the same group the red blood count reaches an ebb at about the seventh week.

The incidence and quantitative interrelations of the symptoms are discussed at length in section 9.

The record of patient Okita is presented as an example of recovery from the severe form of the disease. In general the fatal cases did not present any special symptoms. The tendency was, however, for more of the

signs and symptoms to coexist and to be more severe.

Case Report: Okita, Hirosi

Case Number: H-6011-U*

This 25-year-old soldier was at the 104th Garrison (approximately 1000 meters) on the upper floor of a two story Japanese building at the time of the explosion. Fragments of glass struck his right arm and shoulder, inflicting a laceration on the former and a contusion on the latter. That night he slept in a field but he returned to the Garrison on the 7th. Between the 10th and the 14th he worked on the East Drill Field and was able to march 15 kilometers.

Epilation began on the 20th of August but he continued to work. On the 27th he felt feverish and on the next day petechiae appeared. He was admitted to Ujina Hospital on 30 August. At that time he complained of malaise, headache and swelling of the gums. He had previously had malaise only on the day after the bombing. The gingivae continued to swell and on 4 September they were extremely painful. A week later they began to bleed, but thereafter healing began. He had a sore throat beginning on 1 September and had dysphagia on the 7th. Superficial ulcerations of the angles of the mouth were noted on the next day and he had trismus. His temperature rose sharply on September 1 and attained 40.6° C. on the

*This patient was studied at the Ujina Branch Hospital and later by the Joint Commission. The temperature record is taken from the report of the Japanese Army Medical School.

Laboratory Data:

Blood	RBC	Hgb	WBC	Ly.	M	Myel	Meta. Myel	Stab	Seg	E	Plas-ma	Plate lets
4 Sept	2.6	68%	900	98	2							
8 Sept			1400									
19 Sept			2800	33	9.5	0.5	1.5	21	26	1	6	200,000
27 Sept	2.79	51%	4600	16.5	9.5			3.5	69.5			
23 Oct	3.30	11.5%	10400	40	5.0			2.0	46.0			

Bleeding time (Duke)

24 Sept 3'30"

Clotting time (Sahli and Fonio)

2 Sept 5'30" - 9' (complete)

24 Sept 4'15" - 8'15"

Erythrocyte Fragility test

2 Sept 0.42 - 0.36

26 Sept 0.42 - 0.34

Capillary Resistance test (Neg. pressure method):

13 Sept r' - 120; l - 140

27 Sept r - 260; l - 260

Blood Proteins ($CuSO_4$ method)

23 Oct. 4.6 grams.%

next day. Thereafter it fell by lysis to reach normal levels on the 14th of September. Petechiae began to clear on 9 September and he was sufficiently well on 4 October to be discharged. He was next seen on 23 October 1945 by the members of the Joint Commission, who found him at work at his farm. At this time he complained of shortness of breath upon exertion, but of no other symptoms. The gingivitis was healing anteriorly, but superficial ulcers with purulent bases were still present on the buccal mucosa of the right side (figure 62).

He submitted to a bone marrow puncture and blood count. These showed a remarkable recovery of the leucocyte count to 10,400 on this day, in contrast with its low level of 900 on 4 September, and of the count of nucleated cells in the bone marrow which had risen to 75,000 per cmm on 23 October, from its level of 4,000 on 4 September 1945.

BONE MARROW

Date	4 Sept	27 Sept	23 Oct
Nucleated Cell Count	4000		75,000
Myeloblasts		1.7	3.5
Promyelocytes	0.6	0.8	2.5
N. Myelocytes	8.4	1.7	3.0
N. Metamyelocytes	7.2	12.2	11.5
N. Stab forms	3.0	22.2	17.5
N. Polys	0.6	13.5	12.0
Eosinophiles, all types	7.2	0.4	11.0
Basophiles		0.4	
Lymphocytes	42.1	6.5	24.5
Monocytes	0.6	2.2	1.5
Histiocytes			
Megaloblasts			
Erythroblasts	7.2	2.6	1.5
Normoblasts	8.4	39.1	10.0
Megakaryocytes			
Plasma cells	14.8	1.2	0.5
Unidentifiable (damaged)	25.0	10.0	6.0

Group III (Patients Dying After the Sixth Week)

In some individuals in whom the bone marrow fails to recover or exhibits a maturation defect, the symptoms described for Group II continue and the patients die after a chronic illness. Patients with severe symptoms surviving beyond the sixth week, usually are emaciated.

In others, concomitant with a partial or complete recovery of the marrow, most of the striking manifestations of the aplastic anemia, such as purpura, have disappeared, but they may nevertheless succumb to a pneumonitis or enteritis. These may represent either a new illness of sudden onset, or an exacerbation of a smoldering lesion that had its inception during the earlier leukopenic phase. Thus, lung abscesses may develop in organizing pneumonia. In these patients there is now a leukocytosis. The lesions contain an abundance of polymorphonuclear cells. There is usually no longer a marked thrombocytopenia, but the anemia may be profound. A typical example follows:

Case Report: Kijima, Torowa   Case No.: H-6059-U

Autopsy Key No. 50

Chief Complaint: This 31 year old man was admitted to the Ujina Hospital on 5 September 1945, complaining of epilation, gingival pain and high fever.

Past History: The patient had no noteworthy disease until the present.

Present Illness: At the time of the bombing, he was in military barracks approximately one km. from the center. At this time he sustained a large wound of the occipital region and lacerations of the upper arm and of the dorsum of the left foot. Since the 25th or 27th of August the scalp hair began to fall out and he began to complain of gingival pain and high fever.

Physical Examination: At the time of admission, his temperature was 38.5° C (axillary). The pulse was 102 and regular. He appeared moderately ill. He was pale and undernourished. There was a striking degree of gingival hemorrhage. No increase in the size of the cervical or cubital lymph nodes was noted. Ulcers were present on the lips. It was not possible for him to eat on account of pain. There was striking epilation but no petechiae were seen on the skin.

Course in Hospital: His extermal wounds appeared to heal. He suffered from anorexia. On 10 September he vomited an Ascaris worm. On 15 September fever continued and he had a cough. He became increasingly prostrated and by 18 September, cough was severe enough to disturb his sleep. It was productive of a mucoid and purulent sputum which did not have a strikingly foul odor. Upon standing, it separated into three layers. There was dullness to percussion over the right scapular region and here there was diminution in the breath sounds. There was no change in vocal fremitus. Tubercle bacilli were not found in the sputum when this was examined on 3 October. There were, however, numerous polymorphonuclear leukocytes and cocci. Fever and cough continued through 18 October and the patient continued to suffer from anorexia. An X-ray examination performed on 28 October showed a diffuse cloudiness in the upper, middle and in a portion of the lower lobes of the right lung. The hilar shadows on the left side were accentuated. Auscultation of the chest on 5 November revealed bronchial breathing over the anterior right lung near the apical region. On 14 November there was hemoptysis of approximately 100 cc. Respirations were rapid and the pulse was at this time weak and somewhat irregular. On the 15th, he was in an agonal state and

died at 1120 hours. His total stay in the hospital was 72 days.

Laboratory Data:

Blood	RBC	Hgb	WBC	Ly.	M.	Myel.	Meta Myelo	Stab	Seg	E	B
19 Sep	2.2	36	3200								
8 Oct	1.5	31	4100								
15 Oct	1.8	62	6500	15.5	8.5	0	6	23	49.5	0	0
8 Nov	1.7	35	4300	14	7	5	8	53	8	3	2

Reticulocytes (15 October): 16%

Platelets (15 October): 45,900

Protein ($CuSO_4$ Method, 15 October): 6.69%

	Bone Marrow (17 October '45)	Rib (15 November '45)	Sternum (15 November '45)
Myeloblasts	0.5		
Promyelocytes	0.5		
N. myelocytes	2.9	5.5	7.5
N. metamyelocytes	0.3	10.0	12.5
N. stab. forms	18.0	14.8	14.0
N. polys	36.4	5.5	2.5
Eosinophiles, all types	1.6	1.7	3.0
Atypical lymphocytes		11.0	13.0
Lymphocytes	25.0	35.7	34.5
Monocytes	4.4	1.0	1.0
Erythroblasts	0.5	1.0	
Normoblasts	2.7	6.5	5.5
Plasma cells	1.1	5.0	5.0

Observations at Necropsy

At necropsy the patient was found to be extremely emaciated. There was still a striking degree of epilation of the scalp, and gingivitis was still in evidence. The tongue was almost a perfectly smooth and pale but there were no ulcers and neither the lingual nor faucial tonsils were enlarged or necrotic. There was an organizing and acute pneumonitis of the right side, with multiple abscesses, and bronchiectasis (figure 149 - 151). Fibrous pleural adhesions were present on this side. On the left side there was a focal pneumonia. The bone marrow was hyperplastic, but still showed many atypical mononuclear cells (See Section 8, Group III for description).

The testes were remarkably atrophic (figure 167) as was the adrenal cortex (figure 169).

Notable features of this case are the recovery from the severe symptoms of radiation effect, but the persistence of a pneumonitis, ultimately with formation of an abscess. There is organization of an old pneumonitis, together with an acute focal pneumonia. Profound anemia persisted and there was a relative leukopenia, with, however a marked shift to the left. The bone marrow at necropsy was hyperplastic but showed a persistence of plasma cells and atypical mononuclear cells.

Group IV: Mild Cases:

Persons who were situated near the limit of the range of the radiation or who, although close to the center, were shielded by heavy buildings or who, for unknown reasons, were resistant, manifested mild effects. In some, who were otherwise completely asymptomatic, leukopenia was discovered during a routine blood count. Some merely complained of anorexia and malaise. Diarrhea was a common complaint. Others had mild or even severe epilation without other symptoms. When, however, purpura or oropharyngeal lesions appeared, the patients usually also had epilation and passed through a febrile illness of varying degrees of severity such as was described in its most serious form in Group II.

Most patients with the milder symptoms recovered completely. There were some, however, who had not regained their feeling of well-being even after three months after the bombing. A few of these people had a persistent leukopenia of approximately 3,000-4,000 at the time that the Joint Commission left Hiroshima. A moderate anemia was more common. What role dietary factors played in the anemia is not clear nor is there any information concerning how long depression of the bone marrow may persist.

There follows the history of patient Terachi, who was one of the two known survivors among 23 persons at the Navy Department Office at the Hiroshima Bankers' Club (250 meters). From data presented in Section 11H, she was shielded by the equivalent of approximately 130 inches of water.

Case Report: Terachi, Kazuko
Case No. H-10616-I

This 19-year-old single female telephone operator was in the switchboard room of the Bankers' Club building at 250 meters. She is one of two known to have survived in that building. Information concerning the patient was obtained from her clinical record at the Iwakuni Naval Hospital and from the patient when she was interviewed and examined on 19 November 1945.

The patient was standing at the time of the bombing. She was in a room on the ground floor of a three story concrete building. The windows of the room faced somewhat towards the center of the explosion but there was a concrete wall several feet beyond the windows which did not, however, exert a shielding effect.

She felt the blast come from her left and was lacerated by flying glass fragments over the face, neck, left arm, left leg, left half of the back and right hand. She was not burned. Two other persons were in the room and sustained mechanical injuries. One, Tanaka, Case No. H-10630-I, subsequently developed radiation sickness and died. The other, Kozuka, Case No. H-10633-I, sustained slight burns but lived until 1 November.

The patient escaped from the building in which fire had broken out. At 1700 hours (about 9 hours after the bombing) she became nauseated and vomited many times. These symptoms persisted only during the evening of 6 August, however. She continued to have malaise and was admitted to the Iwakuni Naval Hospital on 9 August with a temperature of 39.9° C. The

extent of infection of her numerous lacerations was not described. Treatment consisted of dressings and sulfanilamide by mouth, 3 grams daily for 3 days. Fever subsided by lysis over a 10 day period. Improvement was sufficient to permit the patient's discharge on 24 August, and her lacerations were completely healed by the beginning of September.

In the end of August, after returning home, the patient developed moderate epilation of the scalp but at no time did she notice any petechiae or other hemorrhagic phenomena. Malaise and weakness were still present when she was examined on 19 November but these complaints were improving steadily. At no time did she have abdominal pains, diarrhea, anorexia, stomatitis or pharyngitis. There was little change in the menstrual cycle. Periods of 4 to 5 days' duration occurred in the beginning of June and July. The August period began on 4 August and ended on the day of the bombing. A 3-day period followed on 5 September and a 3-4 day period on 10 October. There had been no November period at the time of examination on 19 November. On that day her WBC had not as yet reached 5000. Her lowest count had been 1240 on 15 August, 9 days after the bombing.

Laboratory Data:

Laboratory	Date	RBC (millions)	Hbg (grams)	WBC	Other
Iwakuni Hosp	13 Aug	2.40	7.0	3400	Urine: Alb-neg, Sug-neg, Sed few RBC per HPF
Iwakuni Hosp	14 Aug	2.7	5.8	2960	
Iwakuni Hosp	15 Aug	2.3	6.5	1240	
Iwakuni Hosp	16 Aug	2.3	6.2	1250	
Iwakuni Hosp	18 Aug	2.2	5.3	2480	Urine: Alb O. Sug O, Sed Few RBC per HPF
Iwakuni Hosp	20 Aug				Differential: Stab 1, Seg 69, Lym 28, Mono 2.
Joint Comm. (Hiroshima)	19 Nov	3.9	11.5	4500	Differential: Stab 8, Seg 54.4 Ly 27.2, M 4.0, E 4.0, B 0.0, Platelets 65,790 Reticulocytes 0.8%.

Bone Marrow (19 November 1945)

Myeloblasts	2.5
Promyelocytes	2.5
N. Myelocytes	5.5
N. Metamyelocytes	10.5
N. Stab. Forms	25.0
N. Polys.	9.0
Eosinophiles (all types)	4.5
Lymphocytes	27.0

(continued on next page)

Monocytes	2.0
Erythroblasts	2.5
Normoblasts	12.0
Plasma cells	1.0

Note: Some of the lymphocytes are atypical and are difficult to distinguish from promyelocytes.

SUMMARY

The usual clinical observations in the various severe types of disease that have followed exposure to the gamma and associated radiations of the atomic bomb are summarized in table 10. The variability of the symptoms in the mildest cases (Group IV) precludes their cataloguing in tabular form.

TABLE 10

Clinical Manifestations of Severe "Radiation Effect"

MANIFESTATION	Group I 1st & 2d Weeks	Group II 3d - 6th Week	Group III After 6th Week
Epilation	0	+	+
Petechiae	0	+	0
Necrotic Gingivitis and Pharyngitis	0	+	0
Diarrhea	+	+*	+**
Pneumonitis	0	+*	+**
Leukopenia	+	+	0

*Lesions do not contain polymorphonuclears.
**Lesions contain polymorphonuclears.

Note: 1. Nausea and vomiting soon after the bombing were frequent among those who later showed other evidences of radiation.

2. Fever was a common finding in all groups before death.

Fig. 1 (5N)--Takatani. 1000 meters. Patient was in a standing position approximately $3\frac{1}{2}$ meters from a window indoors in a military barracks. Upper torso was as nude as in the photograph but he was wearing trousers. The glass fragments did not penetrate the clothing but only the upper part of the body. Aneurysm of radial artery (see Fig. 2). WBC = 1300 on 24 September 1945. (Photo File #HP 151a.)

Fig. 2 (5H)--Takatani. 1000 meters. Multiple lacerations. Aneurysm of radial artery (see Fig. 1). (Photo File #HP 151b.)

Fig. 3 (5H)--Nurse, Red Cross Hospital. Age ?. Female. 1800 meters. At the time of the bombing she was working in the central wing of the hospital on the 2nd floor. Secondary injury by splintering glass. Dislocation of left wrist and knee joint with fracture. The large windows and dangerous glass splinters in this hospital are illustrated in Fig. 24 (Section 3H). (Photo File #HH 129.)

Fig. 4 (5H)--Name of patient unknown. Age ?. 1000 meters. No burns. Laceration of left eyeball, left infra-auricular region, and left shoulder by splintering glass. WBC: 15 September, 2500; 20 September, 3500. 5 September, enucleation of left eyeball on account of suppurative process extending into vitreous. A patient of the Post-Office Hospital. (Photo File #HH 200.)

Fig. 5 (5H)--Toshi Sasaki. Age 23. Male. 1400 meters. At time of bombing, he was sitting at work in Toyo Steel factory. Saw flash and began to rise when blast was felt. Sustained secondary injury by falling beams. Injuries: Incomplete fracture of head of tibia and multiple lacerations. No nerve injury. Subsequent ankylosis of knee joint. No impairment of movement of feet and toes. Leg held in semi fixed position on account of pain. WBC 6200. This man was a patient at the Red Cross Hospital. The supporting beams of some typical Japanese houses, such as may have inflicted this type of injury are shown in Figs. 20-22, Section (3H). (Photo File #HH 127.)

Fig. 6 (5H)--Telephone pole at Meiji bridge. 1300 meters. Shadow of leaf pattern. This proves the brevity of the period of action of the heat rays, since the shadows of the leaves that once projected above the present new growth, are sharply outlined. The heat was sufficient to wither the leaves but did not kill the entire plant. (Photo File #HE 113b.)

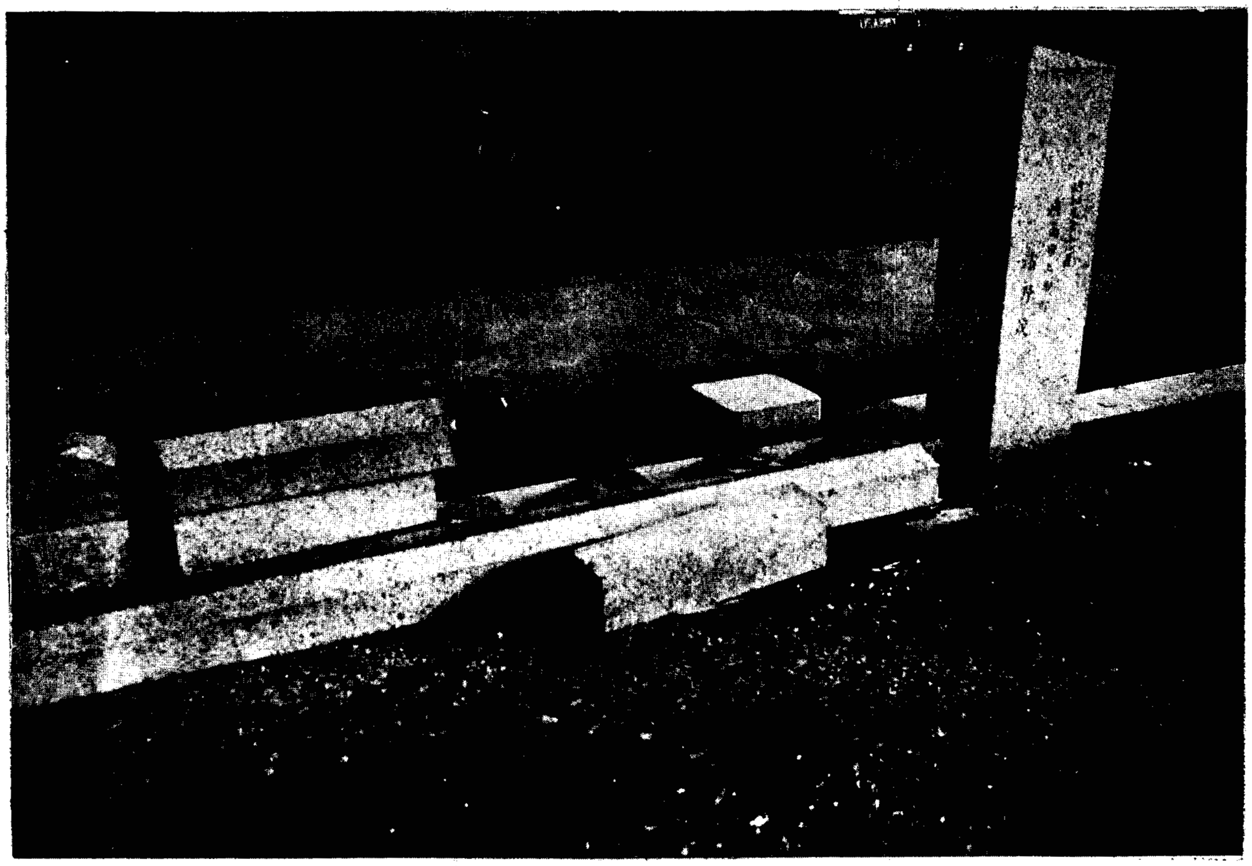


Fig. 7 (5H)--Gokoku Shrine--Granite Post Shadows. Effect of heat rays on granite. The affected material now appears lighter than that protected by the shading effect of the originally upright posts. This is proof that the high temperature produced its effect in the fraction of a second before the posts were upset by the blast. Approximately 650 meters from the actual point of explosion (airburst). (Photo File #HE 112 (K).)

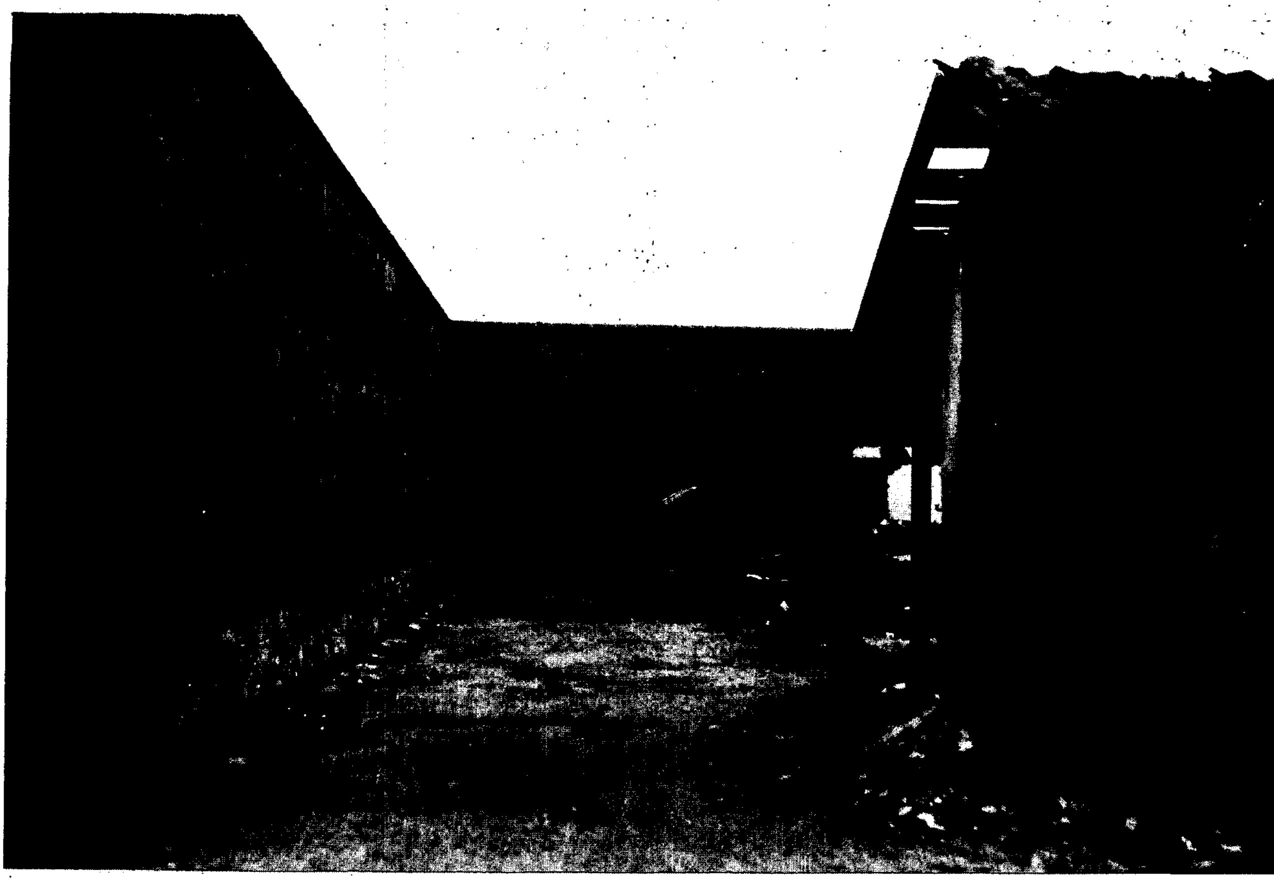


Fig. 8 (5H)--Prison outer wall "Shadow." 2300 meters. The dark color of the far wall is its appearance before the explosion. Much of the lichen has been killed in the path of the heat rays. The dead lichen has a very light grey color. On the shaded wall, at the left, in its living state, it has a dark appearance. (Photo File #HE 115.)

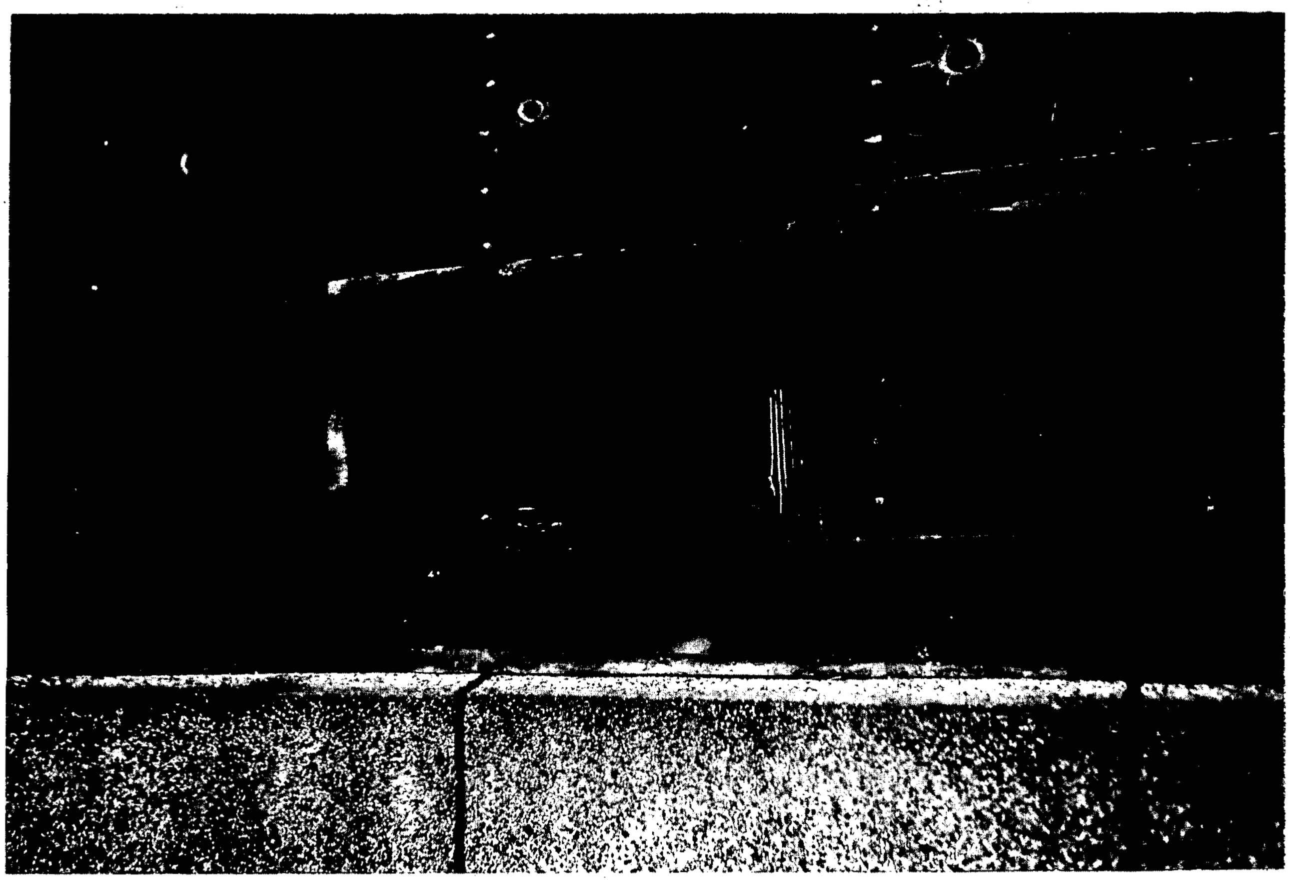


Fig. 9 (5H)--Prison. Shadows of water pipe. Horizontal shadow cast by the transverse pipe; vertical shadow cast by the projecting lath to the right of the vent; vertical and horizontal shadow cast by the "L" pipe. Study of these "shadows" gives information concerning the lateral and upward angle of the center of the explosion. By triangulation, the position of the center was determined from such data. (Photo File #HE 114.)

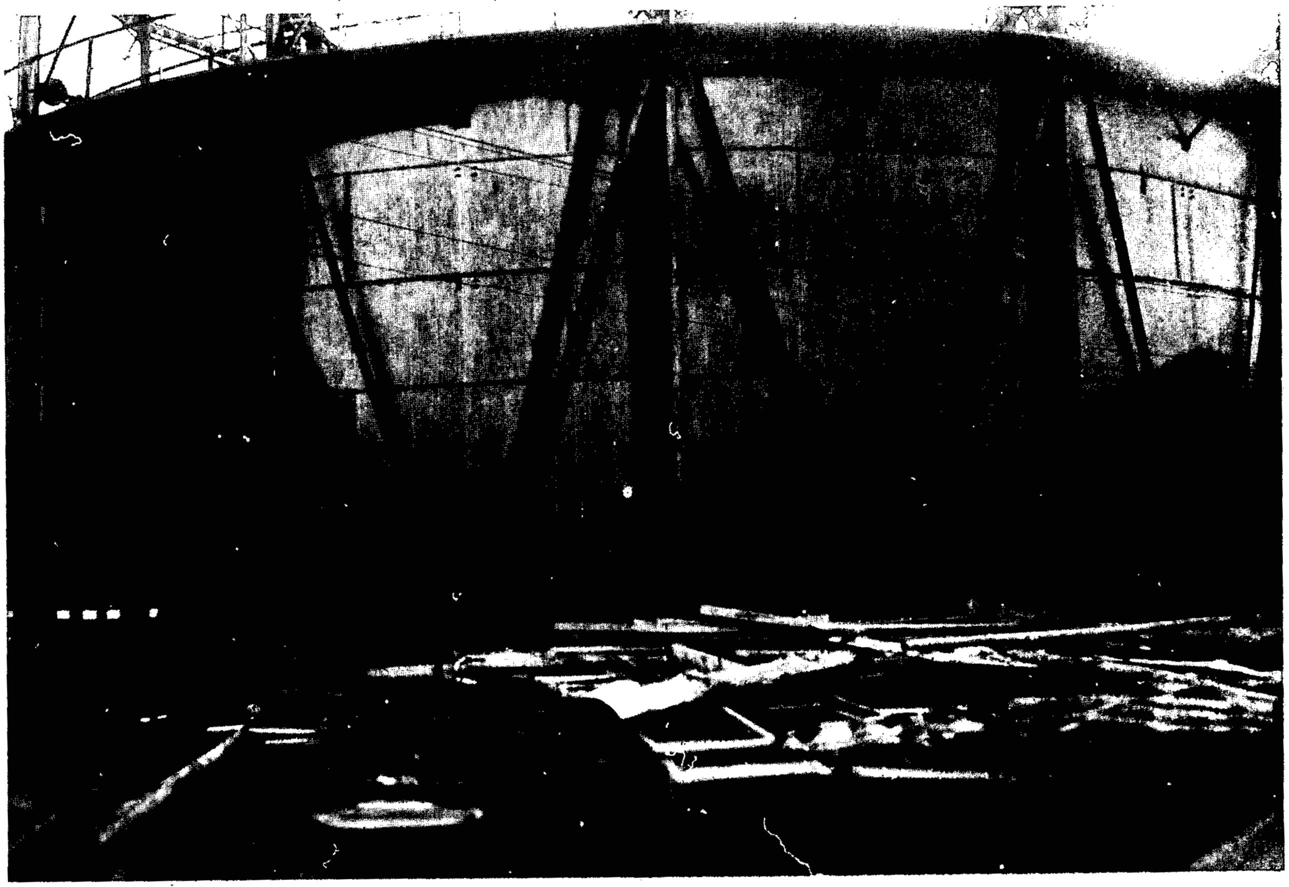


Fig. 10 (5H)--Gas Tank. 2300 meters. Shadows produced when the radiant heat changed the paint of the tank from black to grey. Note the unburned section of the asphalt tank at the left. The triangular shadow is that of a building that was destroyed shortly after the flash by the blast. (Photo File #HE 120.)

Fig. 11 (5H)--1700 meters. Shadow cast by the window frames in the Post-Office Savings Bank. People in this building were said to have been burned through the window glass. (Photo File #HE 137.)

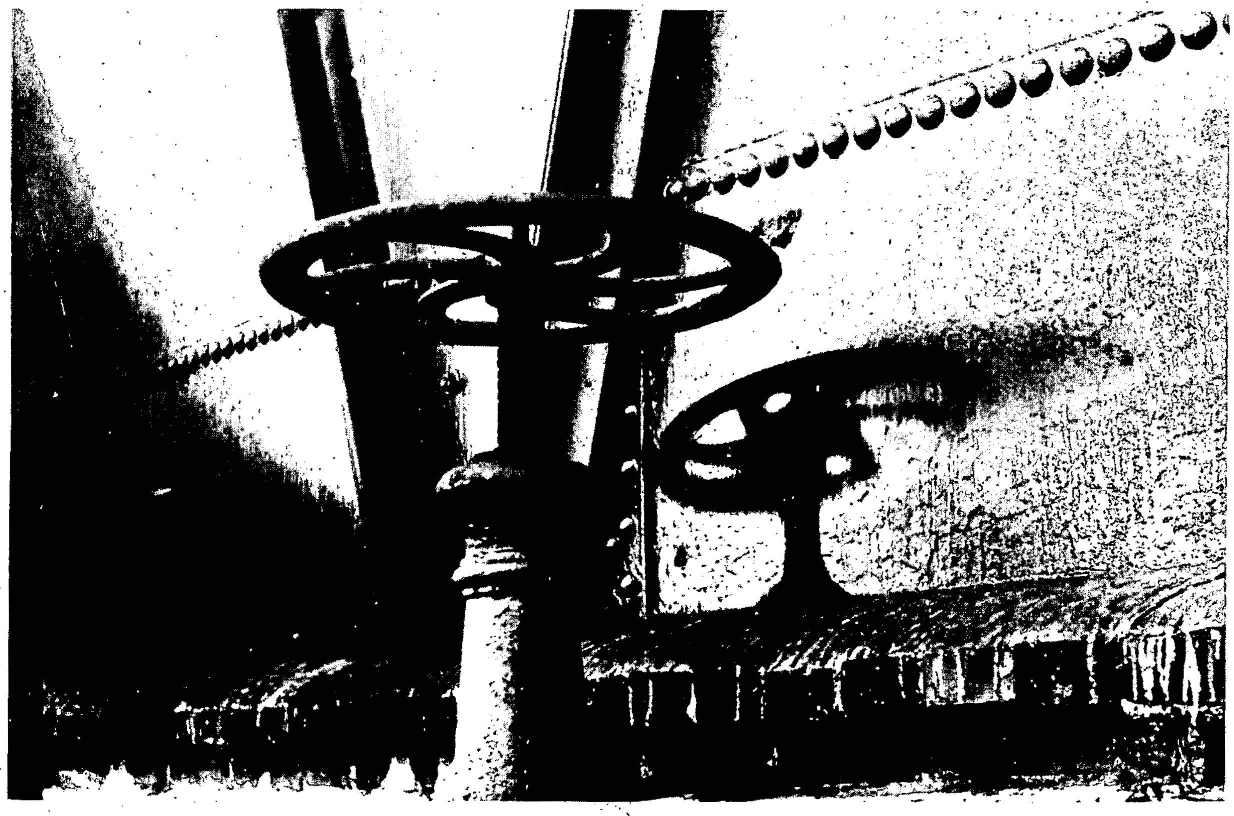


Fig. 12 (5H)--Shadow cast by valve on gas tank. 2300 meters. (Photo File #HE 138.)

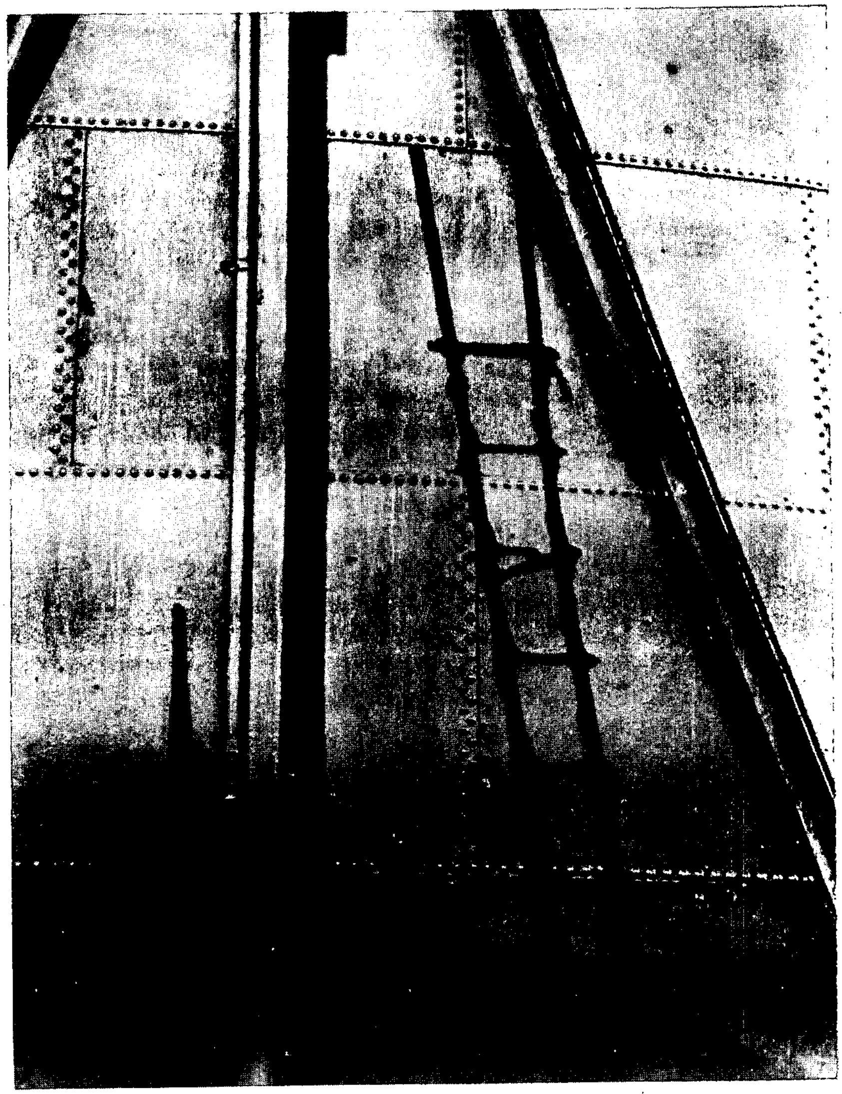


Fig. 13 (5H)--Shadow of ladder burned on gas tank at Minami-cho, approximately 2.2 kilometers from the center of the explosion. (Photo File #HE 135.)

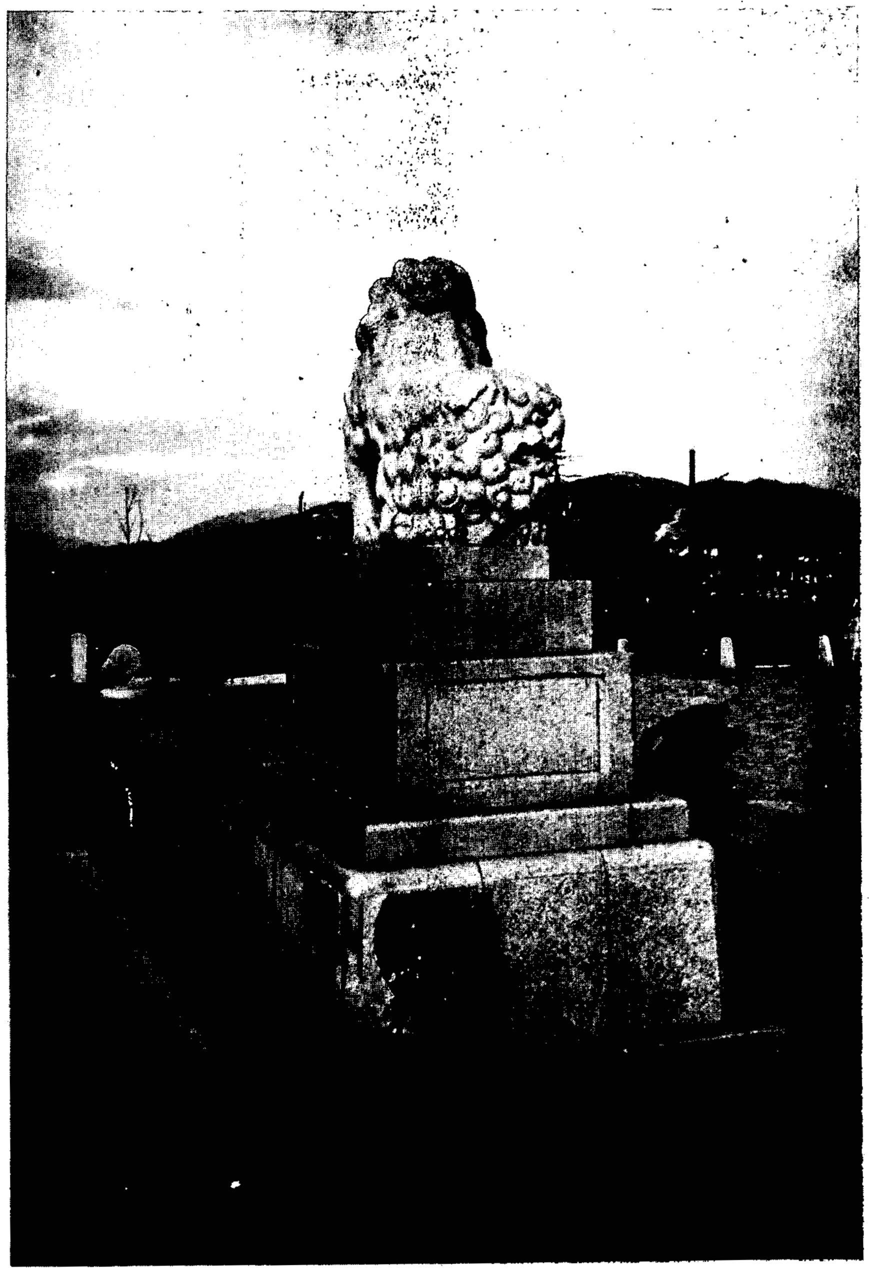


Fig. 14 (5H)--Gokoku Shrine (300 meters). General view of pedestal of a guardian dog at the shrine. The granite that was shaded retains it polish on the left side of the pedestal at the several levels; that which was exposed to the radiant heat is rough and light in color. This suggested to Japanese experts that at the surface of the granite, the temperature was as high as 2500°C. (Photo File #HE 108.)

Fig. 15 (5H)--Gokoku Shrine (300 meters). Sighting along the line of junction of the polished and roughened granite directly toward the center. Note the triangular metal tower near the point above which the bomb exploded. This was sighted from the opposite side in Fig. 18 (5H) by a similar procedure. (Photo File #HE 111 (K).)

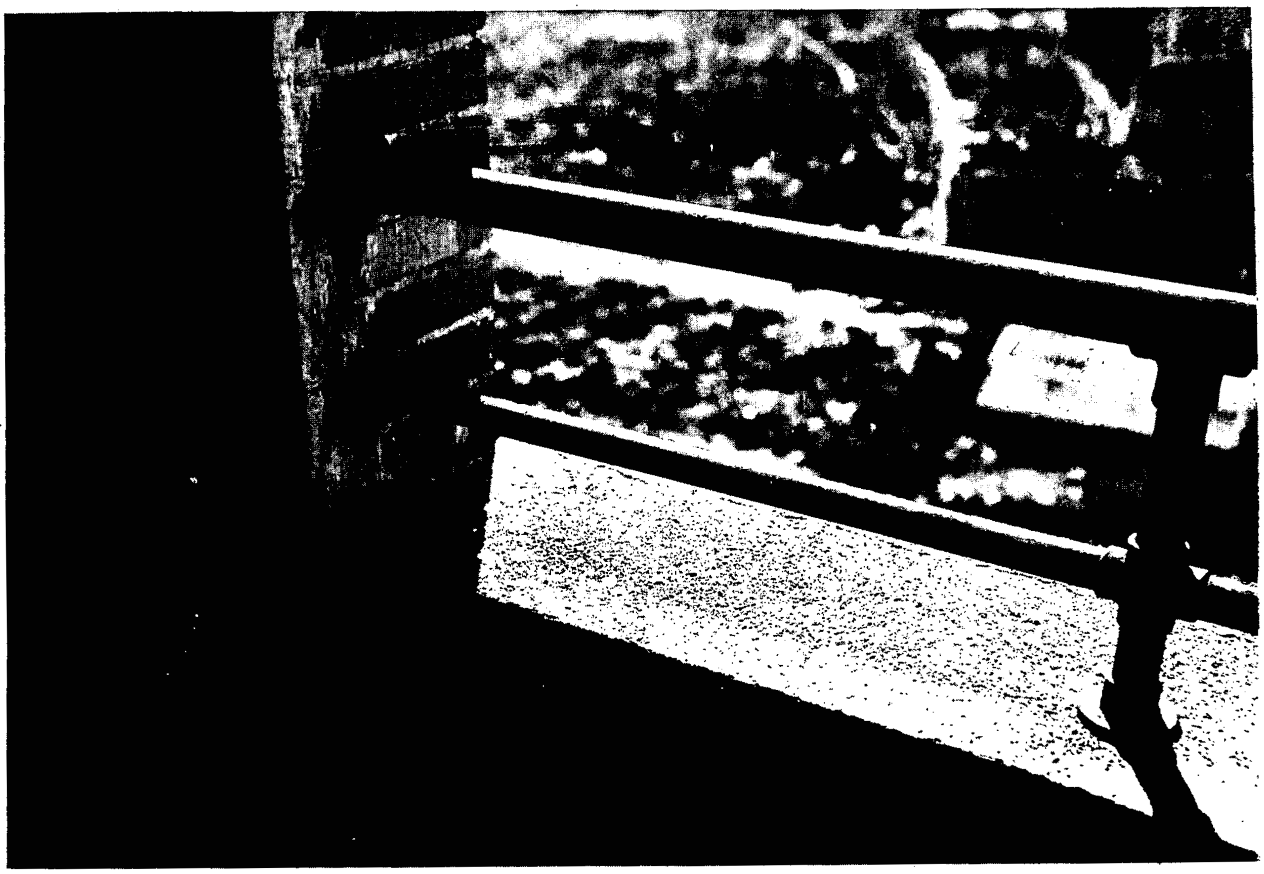


Fig. 16 (5H)--Railing near top of Business Men's Club (300 meters). The railing has cast a double "shadow" caused presumably by an umbra-penumbra effect of the "ball of fire." The broad pale line nearest the observer represents the umbra, the darker line is the penumbra. That these effects are not artefact is shown by the fact that the line stops near the left of the photo at a point corresponding to the shadowing effect of the upright wall at the left. (Photo File #HE 119b.)

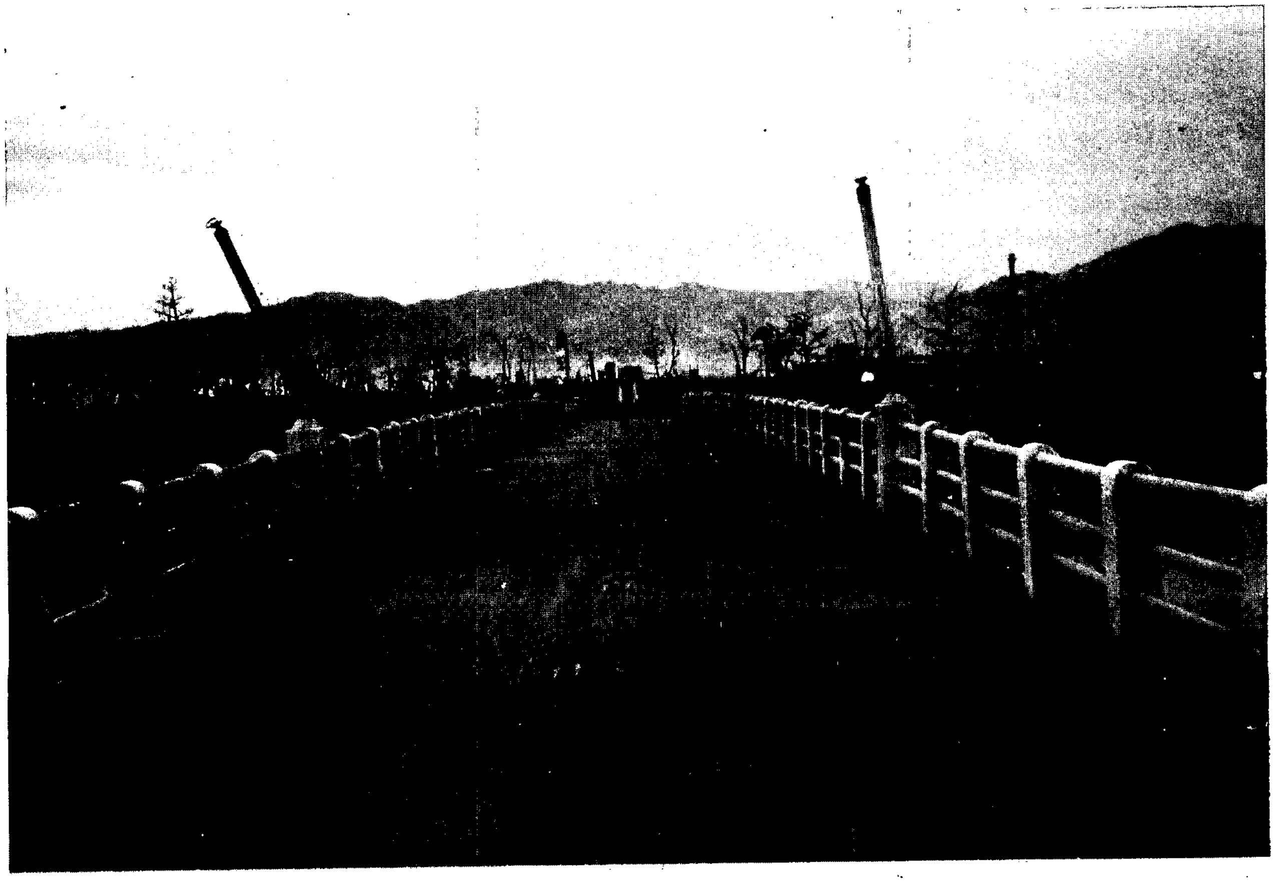


Fig. 17 (5H)--Bantai Bridge (1000 meters). White "shadows" left when the surface of the asphalt was darkened by the heat waves produced by the explosion. (Photo File #HE 100.)

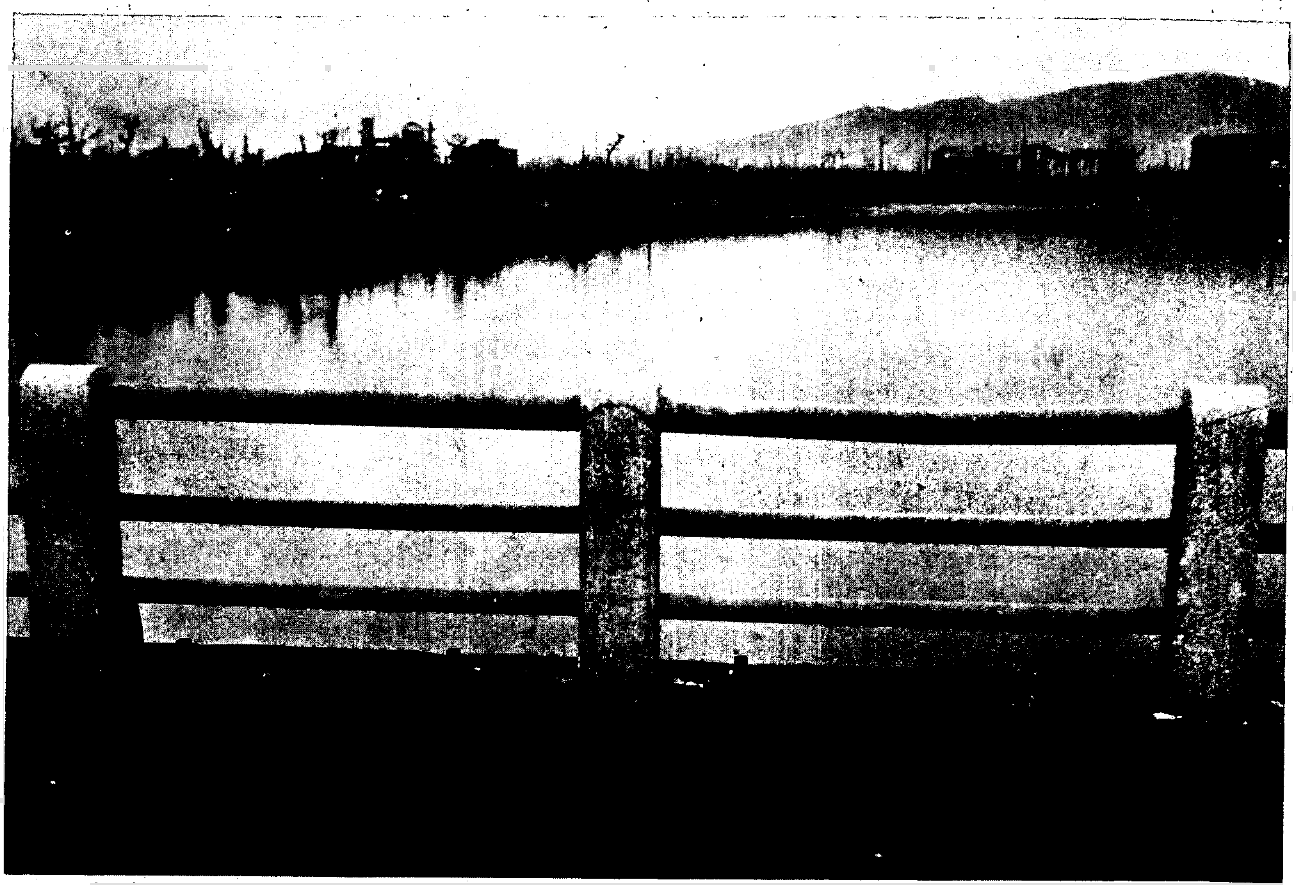


Fig. 18 (5H)--Bantai Bridge (1000 meters). The "shadow," centered upon the upright which produced it, points directly toward the center of the explosion. Compare with Fig. 15 (5H), where the triangular steel tower near the center is seen from the opposite side. (Photo File #HE 102.)

Fig. 19 (5H)--Bantai Bridge (1000 meters). "Shadow" of a human being on the asphalt of the bridge. (Photo File #HE 103.)

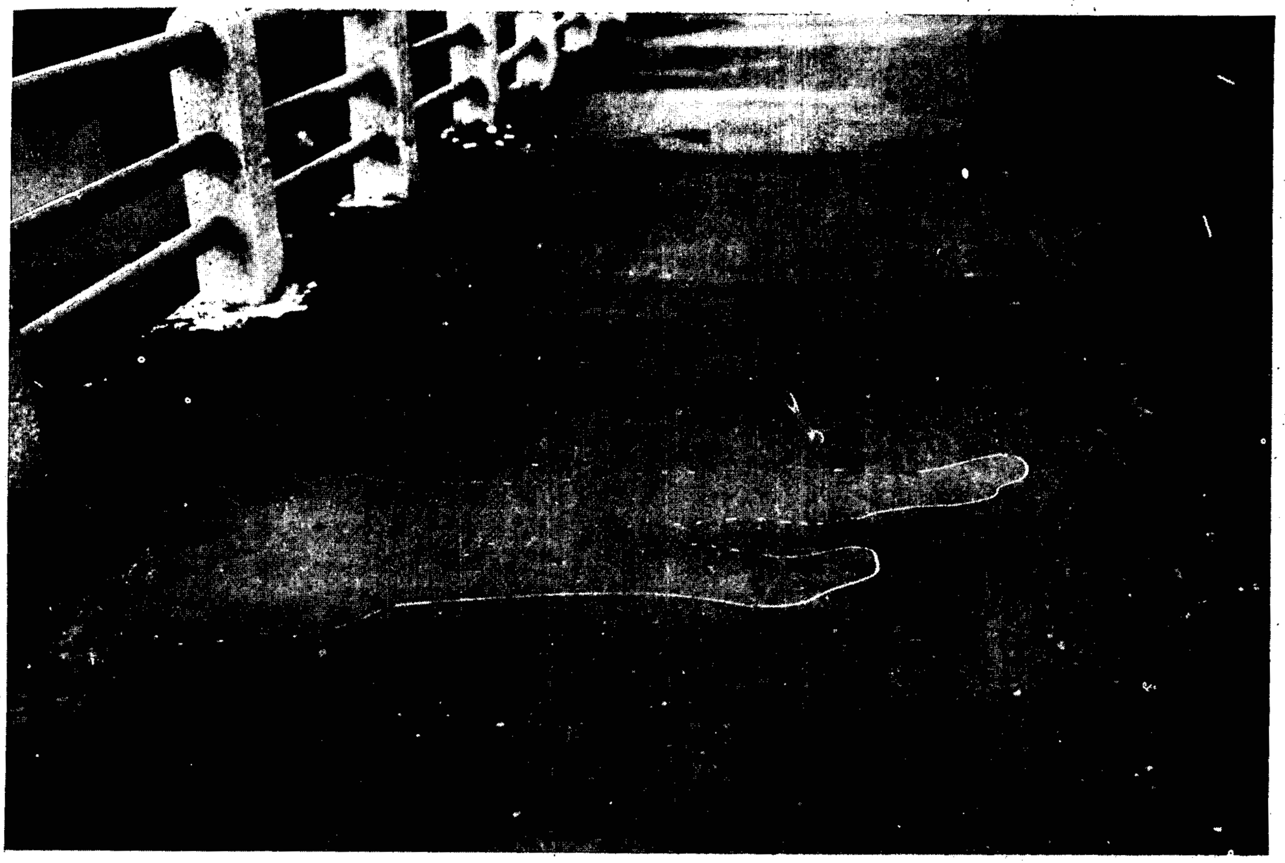


Fig. 20 (5H)--Bantai Bridge (1000 meters). Same as Fig. 19, outlined in chalk. (Photo File #HE 105.)

Fig. 21 (5H)--Bantai Bridge. Man standing on the outlines of the footprints shown in Fig. 19. Photographed in flat light. (Photo File #HE 104.)

Fig. 22 (5H)--Bantai Bridge. "Shadows" of a cart and human beings. (Photo File #HE 106.)

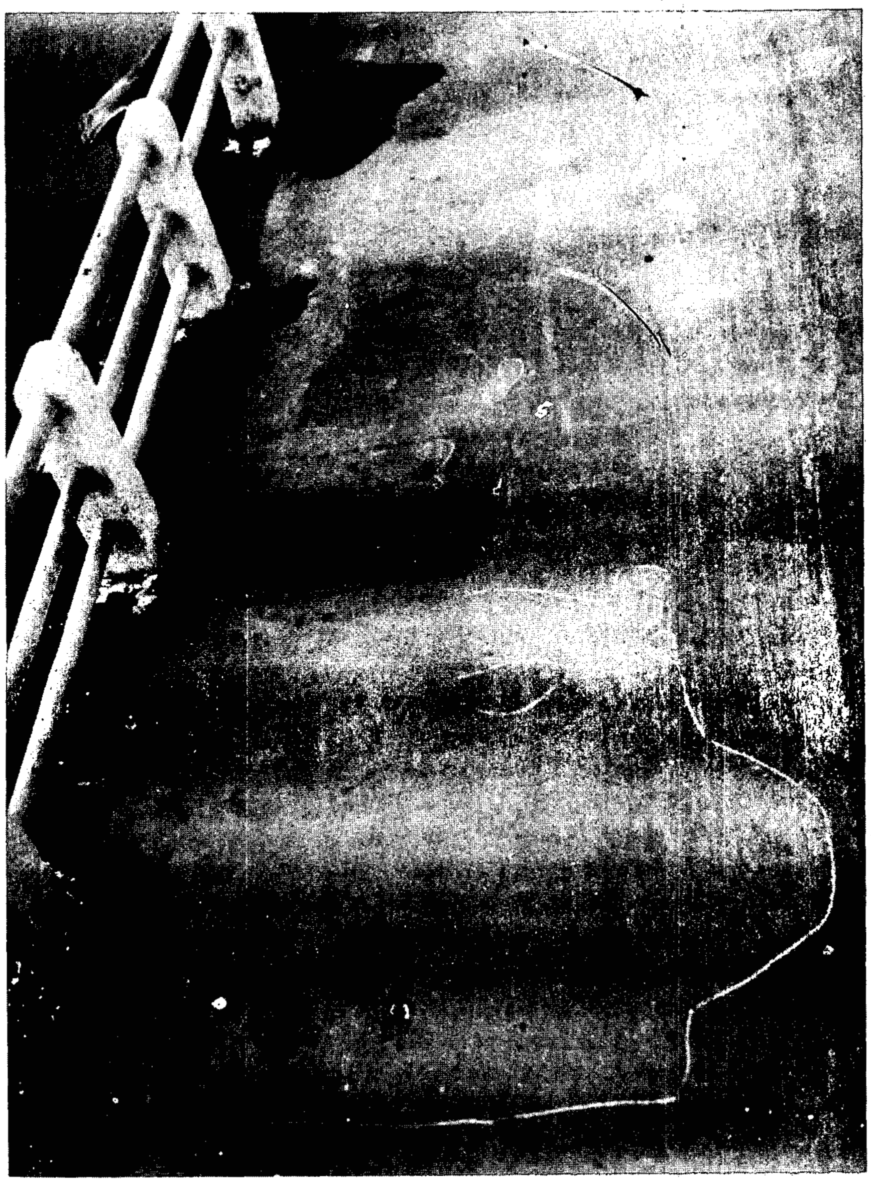


Fig. 23 (5H)--Bantai Bridge. "Shadows" shown in Fig. 22, outlined in chalk. (Photo File #HE 107.)

Fig. 24 (5H)--"Flash burns," effect on orange (2600 meters). This is analogous to the burning and subsequent scarring in the human skin. The burn in this instance did not penetrate deeply enough to kill the plant. (Photo File #HE 139.)

Fig. 25 (5H)--Iida. Age ?. Male. 2000 meters. (See Figs. 26 and 27.) Mild keratitis and conjunctivitis. This was one of the few patients in whom the lesion persisted until October (8 weeks after the bombing). (Photo File #HP 145c.)

Fig. 26 (5H)--Iida. Age ?. Male. 2000 meters. Patient was in a running position dressed in military uniform. Rays received from left and anteriorly. Slight keratitis of both eyes (see Fig. 25). (Photo File #HP 145b.)

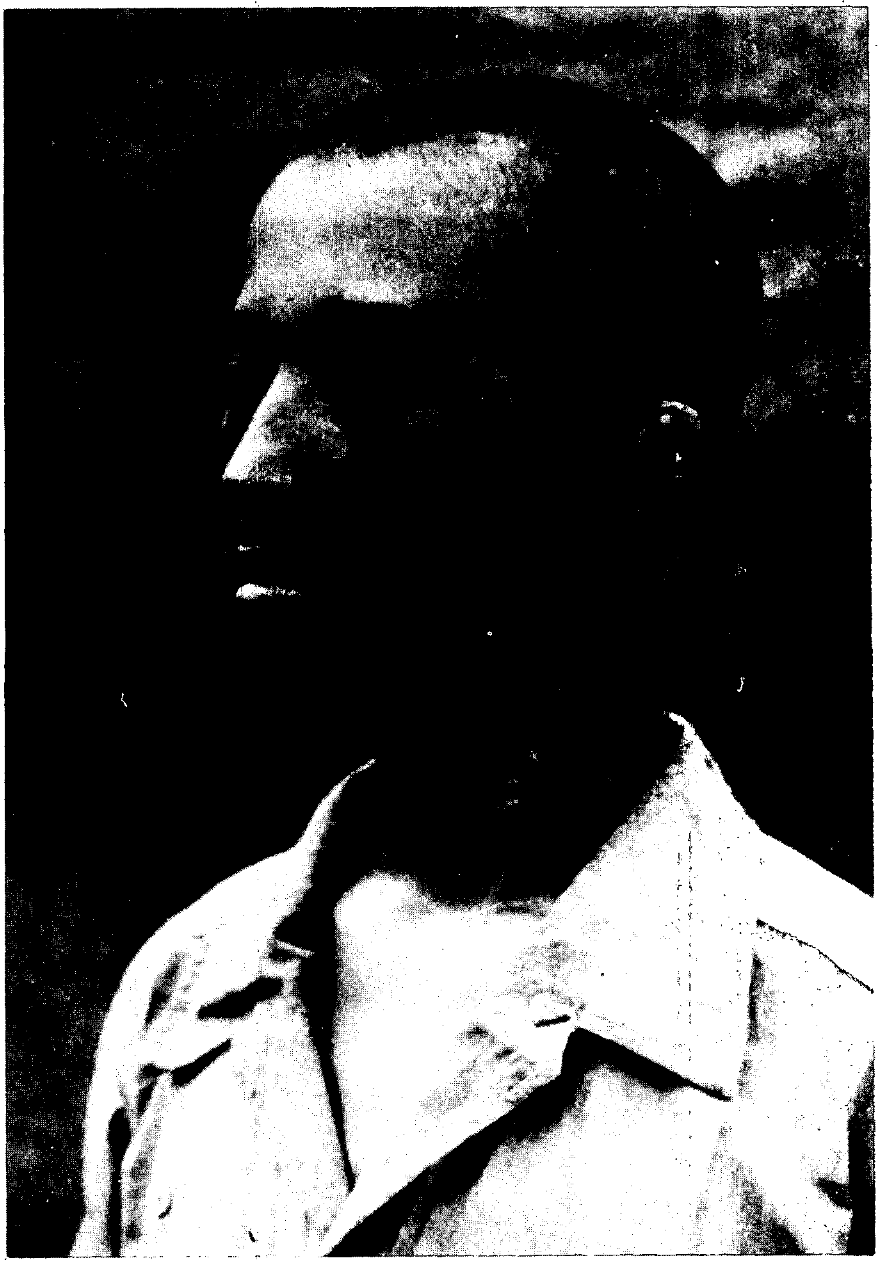


Fig. 27 (5H)--Iida. Age ?. Male. 2000 meters. Patient's head protected by hat (compare with preceding figure). Shading of submandibular region. Clothes protected the lower portion of the neck. Note the intense mask-like pigmentation common at this distance. The pigment is most intense at the margin of the lesion. Just outside of the skin it is even paler than elsewhere. (Photo File #HP 145a.)

Fig. 28 (5H)--Kosugi. Case #0-11170-R. Age 17. Female. 1700 meters. Wearing white half-sleeved shirt and white slip and black mompe. Flash burns. Typical profile burn. Depigmentation sharply outlined by pigmented tissues in a very narrow band. The line of the burn extends upward on the chin. The darker material in the peri-aural region is not pigmented tissue, but is a crusted exudate and keratin. (Photo File #HP 117 (K).)

Fig. 29 (5H)--Name and distance from bomb unknown. "Flash burn" of back. Note that the long hair has protected the patient's head. Crusting, cracking, and darkening of the skin. The burn is nevertheless superficial and edema is not a striking feature. Date of photo probably mid-August, but exact date unknown. (Photo File #HP 140.)

Fig. 30 (5H)--Name and distance unknown. "Flash burn." The burns seem deeper than in the preceding figure. The short hair in the present case did not protect the scalp. Date of photo probably mid-August, but exact date unknown. (Photo File #HP 142.)

Fig. 31 (5H)--Sasomoto. Case #H-6069-U. Age 27. Male. 1400 meters. Soldier, standing in the open, clothed in khaki uniform. "Flash Burns." Depigmentation at center of "profile burn." Protection by collar, with sharp neck line. Double contoured margin at lower border of the burned areas (hyperpigmentation-depigmentation). Scarring in region of elbow. (Photo File #HP 101 (K).)

Fig. 32 (5H)--Hayashi. Case #H-6054-U. Age 47. Male. 1500-2000 meters. Patient, a soldier was riding a bicycle. Was wearing a shirt, trousers, shoes and stockings. "Flash Burns." Typical V-line of burn of neck. Burn beneath the clothing, most severe where tightly stretched, in path of the ray, as at right shoulder in this instance. Shaded (supra-thyroid) portion of neck is spared. Scarring with contracture at right elbow. No evidence of radiation. (Photo File #HP 100 (K).)

Fig. 33 (5H)--Kambara. Case #H-6079-U. Age 18. Male. 2100 meters. "Flash Burn." Sharp demarcation. Scaling and some scarring over most of the burn. Pigmented outline. Narrow band of paler skin on the outside of the line of pigmentation. Epilation in the burned area. Protection by hat. (Photo File #HP 102 (K).)

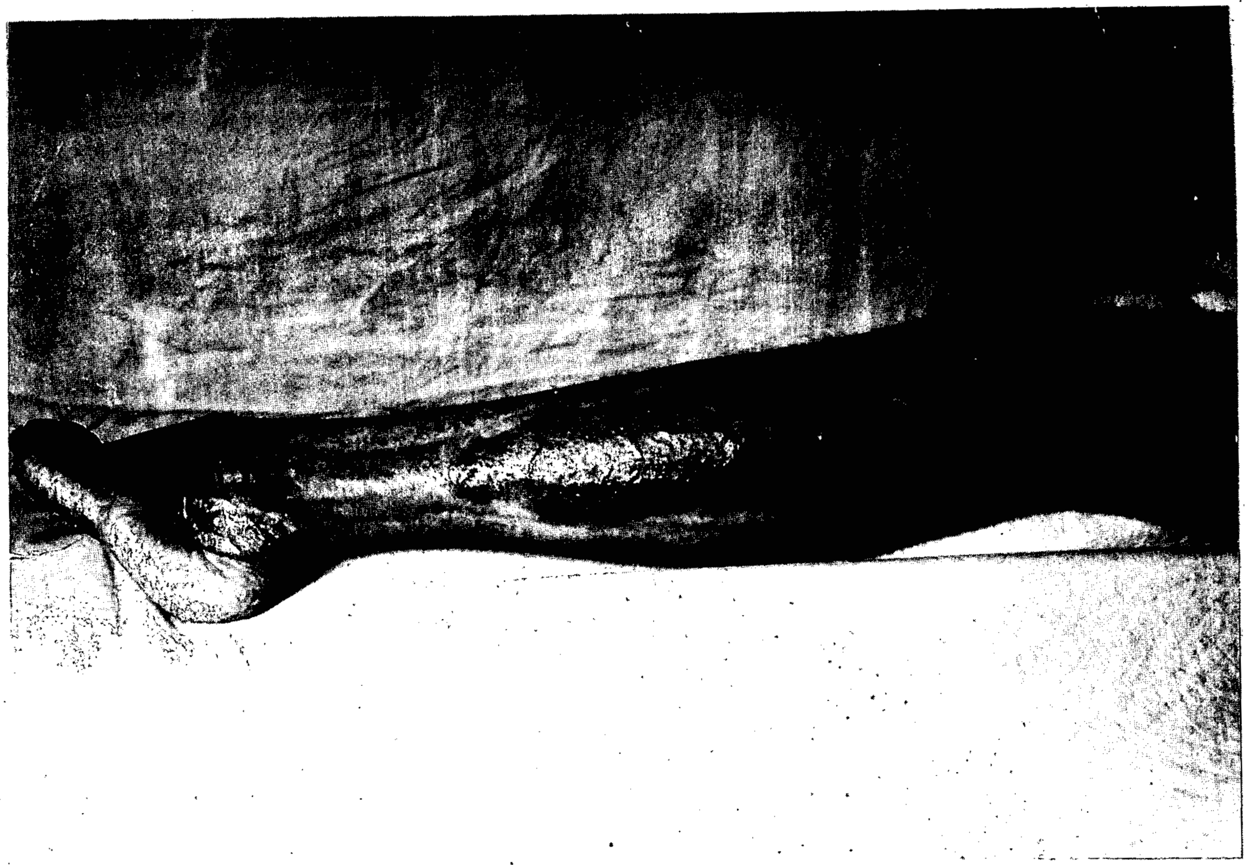


Fig. 34 (5H)--Kambara. Case #H-6079-U. Age 18. Male. 2100 meters. Leg: Typical "flash burn." Depigmented area, red at center, white marginally, outlined by dark brown narrow, pigmented band. Narrow zone of depigmented tissue externally of this. Scarring with keloidal changes at center. (Photo File #HP 103 (K).)

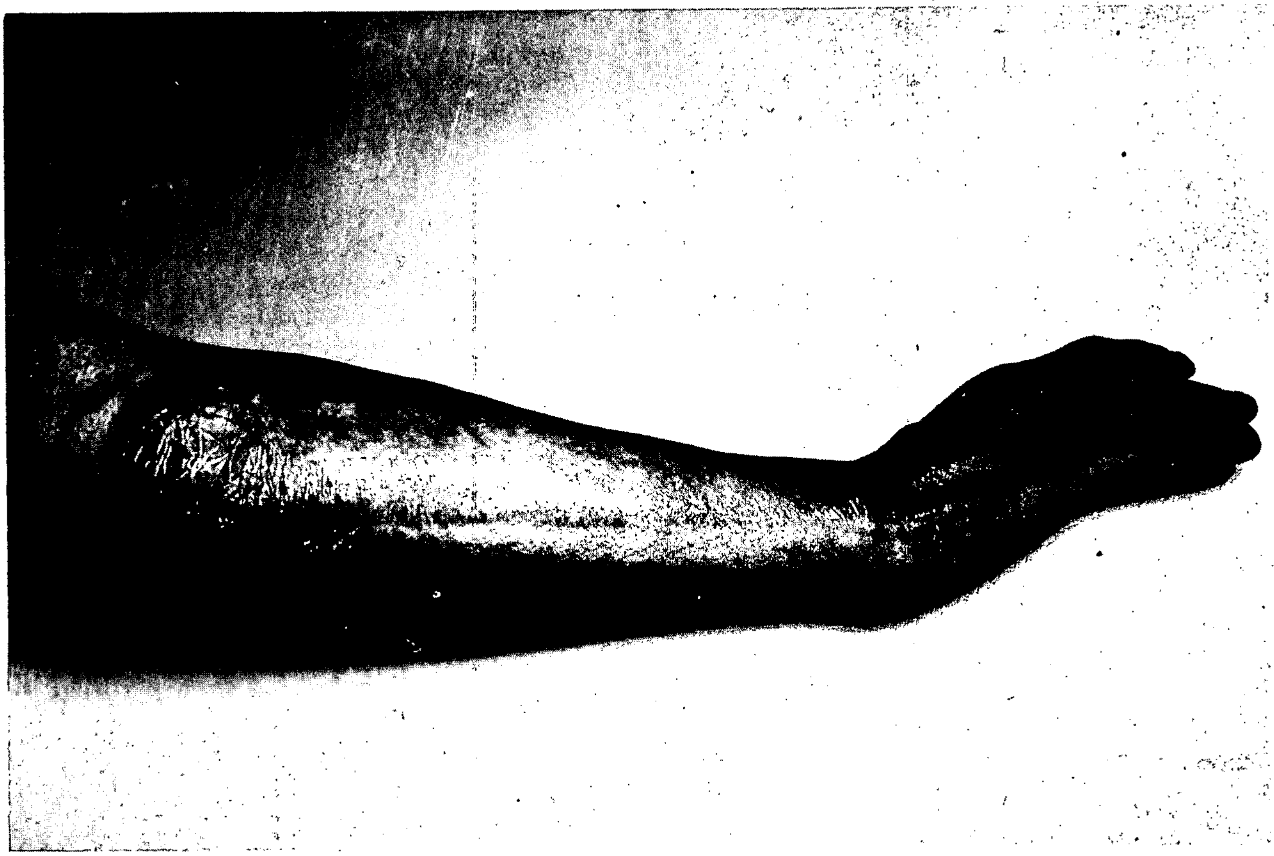


Fig. 35 (5H)--Shinsho. Case #0-10282-P. Age 43. Male. 1500 meters. Patient out of doors near wooden buildings. Wearing white half-sleeved shirt. "Flash burns." Sharply demarcated "profile" burn of arm. No burns of the skin where fingers were in contact. Coppery red slightly projecting tissue at the center. Narrow hyperpigmented band at margin. Note that scarring has occurred in the distal portion of the arm where it was naked. In the upper arm which was protected by white shirting, there is no scarring, and only slight depigmentation near the center of the lesion. (Photo File #HP 110 (K).)

Fig. 36 (5H)--Takemoto. Case #0-10281-P. Age 49. Female. 1400 meters. Flash burns. Left side of face. Bomb to left and anteriorly of patient. Deep chocolate brown mask of pigmentation. Sharp v-line of neck. Burns over left deltoid region. Protection by shading of upper part of neck. In this dark-skinned patient there is only slight depigmentation in the central parts of the lesion without scarring and particularly dark pigmentation elsewhere. (Photo File #HP 109a.)

Fig. 37 (5H)--Takemoto. Case #0-10281-P. Age 49. Female. 1400 meters. Flash burns (compare with 36). Right side of face. No burns of right shoulder. Burns of face extend only slightly upon the right side. (Photo File #HP 109b (K).)

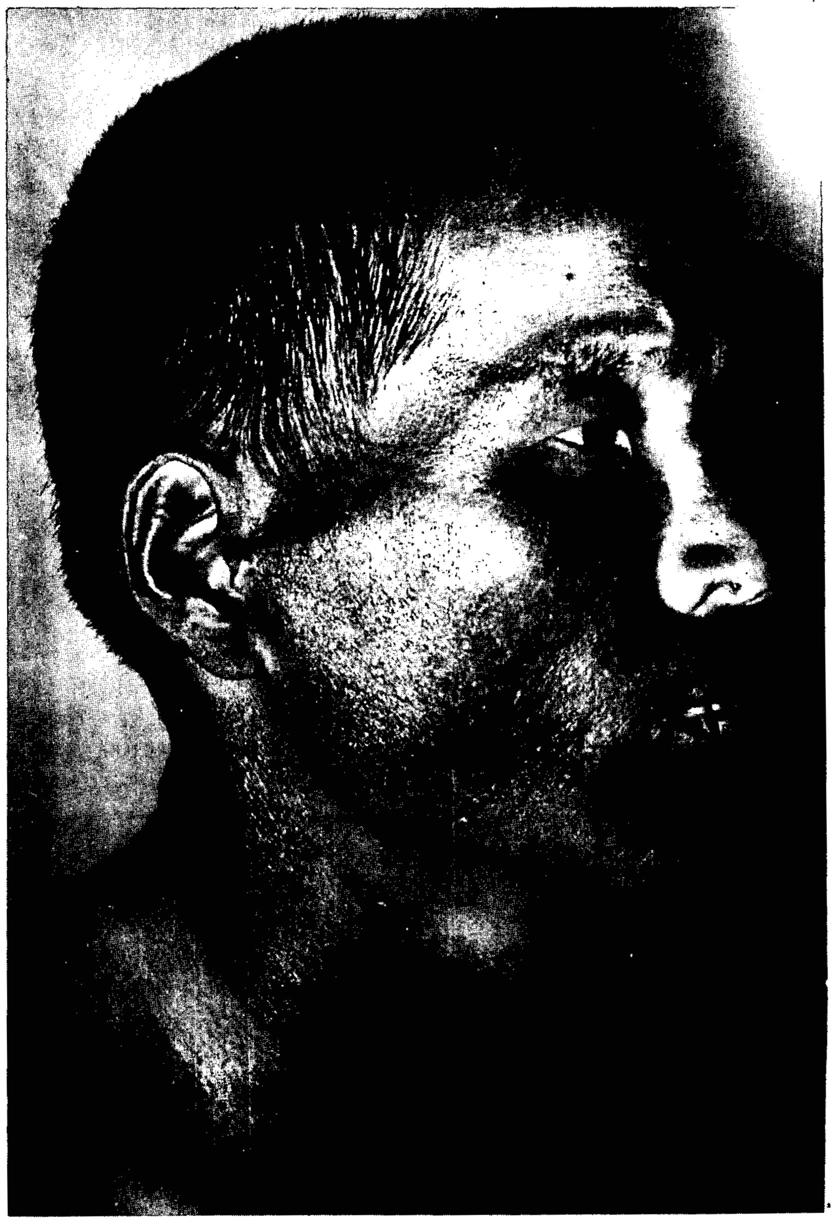


Fig. 38 (5H)--Enami. Case #S-11259-Pr. Age 30. Male. 2300 meters. Patient wearing blue long-sleeved prisoner's coat and shirt and a blue cap which was scorched. "Ray burns". Typical profile burn with deep chocolate-brown pigmentation. Very sharp outline. Protection of upper portion of neck by mandibular shading. Note that nasolabial groove and lateral nasal groove were protected by the projecting adjacent parts. No burns beneath the clothing at this distance. (Photo File #HP 112b (K).)

Fig. 39 (5H)--Enami. Case #11259-Pr. Age 30. Male. 2300 meters. "Flash burns." Mask burn of right side of face and neck. Protection of sub-nasal and sub-labial regions by shading. Patient is attempting to demonstrate this point by retracting his lips (see Fig. 38). (Photo File #HP 112a (K).)

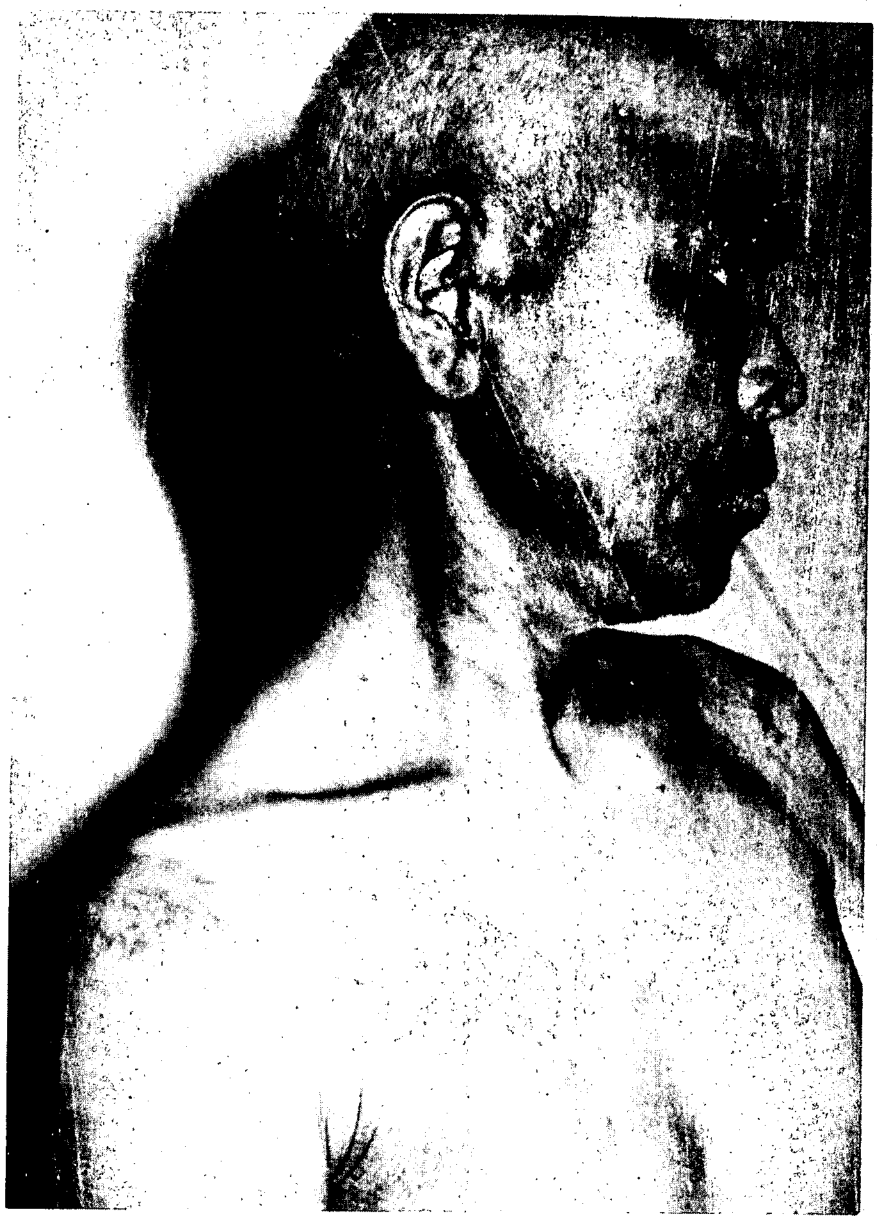


Fig. 40 (5H)--Okida. Prisoner. Case #S-11360-Pr. Male. Age 55. 2300 meters. Wearing long-sleeved blue undershirt and a blue cap which was charred. "Flash burns." Bomb to right and anteriorly of patient. Typical dark red-brown "Mask." Burns of the projecting deltoid and pectoral regions. Protection by shading of sub-mandibular regions. (Photo File #HP 113 (K).)

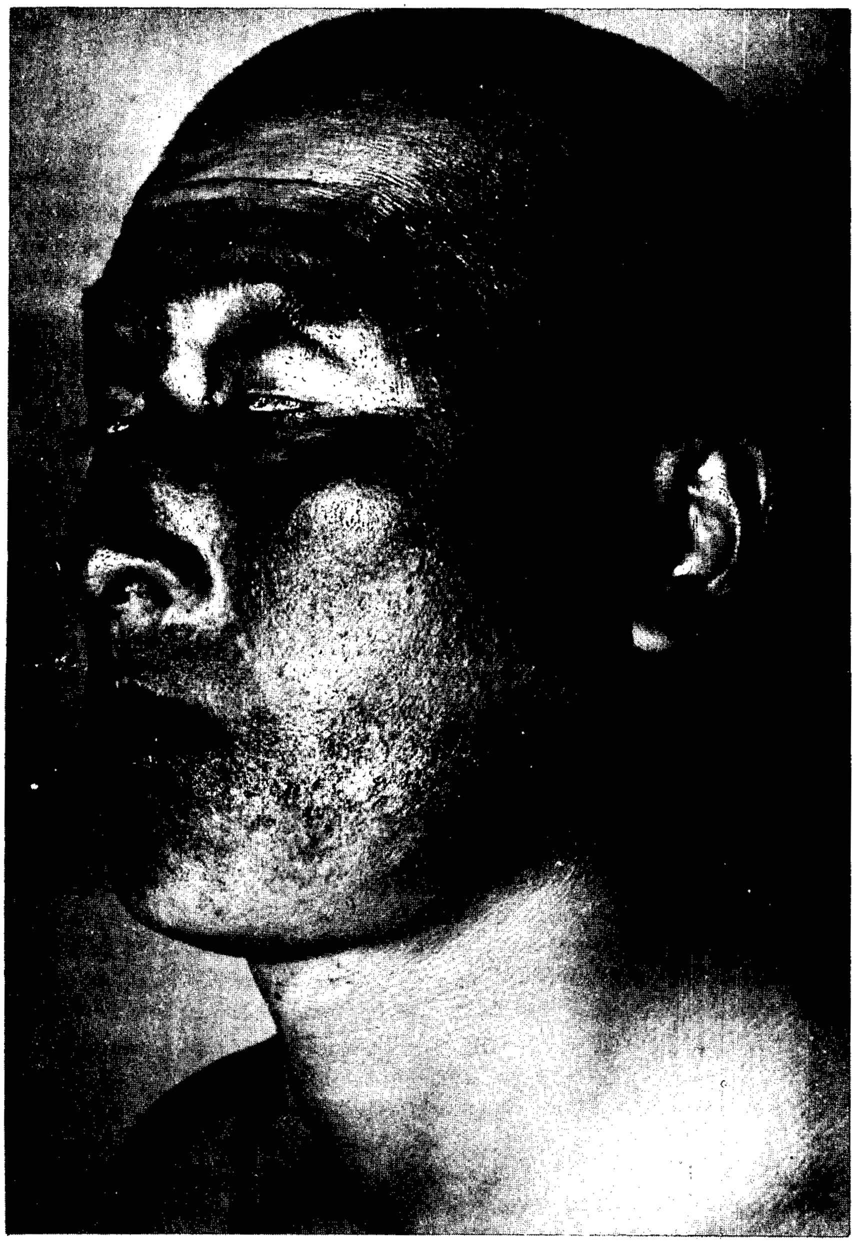


Fig. 41 (5H)--Narumi. Case #S-11377-Pr. Age ?. Male. 2300 meters. "Ray burns." Dark chocolate brown pigmentation of left side of face. Much slighter pigmentation of the upper eyelids as compared with the tissue just beneath the brows. Presumably the lids were closed before serious burning could occur. Patient is raising his eye-brows to demonstrate this point. (Photo File #HP 114 (K).)

Fig. 42 (5H)--Maeda. Case #S-11378-Pr. Age 40. Male. 2300 meters. Prisoner, wearing blue coat and trousers. Flash burns. Typical "profile" burn. Shading by mandible and collar. Burns of the deltoid and trapezius regions over which the clothing was tightly stretched. Characteristic pigmentation (see Fig. 43). (Photo File #HP 115a (K).)

Fig. 43 (5H)--Maeda. Case #S-11378-Pr. Age 40. Prisoner. Male. Flash burns (close-up): Detail of shoulder. Mottled depigmentation in central portions where the burn was most severe. Hyperpigmentation elsewhere, but again there is a narrow zone of depigmentation between the normal skin and the burned area. (Photo File #HP 115b (K).)

Fig. 44 (5H)--Namba. Case #H-11741-OM. Age 21. Male. Between 1000 and 1500 meters. Patient wearing Japanese khaki uniform. Left shoulder burns through clothes. Depigmented tissue at center, surrounded by zone of hyperpigmentation, which in turn is outlined by depigmented tissue that blends with the normal skin. (Photo File #HP 122.)

Fig. 45 (5H)--Miura. Case #H-6306-U. Age 19. Female. 1800 meters. Standing outdoors in the open. "Flash burn of face." The burned area in this light-skinned individual is bright red with faint red-brown marginal pigmentation. (Photo File #HP 104 (K).)

Fig. 46 (5H)--Akamatsu. Case #0-1097-P. Age 21. Female. 1400 meters. Out of doors in the open. Wearing red-patterned silk half-sleeved blouse and white cotton slip and mompei. Blouse became charred. "Flash burns." Formation of keloids. Copper-red tissue at center. Dark red-brown hyperpigmented zone at margins of the lesions in this light-skinned patient. Some protection afforded by seams of the blouse and by straps of the undergarment or mompe. (Photo File #HP 111a (K).)

Fig. 47 (5H)--Akamatsu. Case #10976-P. Age 21. Female. 1400 meters. "Flash burns." Close up of Fig. 46. (Photo File #HP 111b (K).)

Fig. 48 (5H)--Fuchimoto. Case #H-11739-OM. Age 21. Male. 1000-1500 meters. Outdoors in the open wearing military uniform, hat and shoes. Some burns of back through the clothing. Slight epilation. WBC on 28 August were 2400; WBC on 5 November were 5400. Typical "profile burn" with depigmentation and scarring. (Photo File #HP 120.)

Fig. 49 (5H)--Sano. Case #H-11725-OM. Age 23. Male. 1000 meters. Out of doors in open. Wearing soldier's uniform, hat and shoes. Typical profile burn. Chondritis of ear, with scarring. Burns also through khaki uniform in scapular region. Epilation 20 August 1945, well on way to regeneration on 28 November 1945. WBC 28 August were 1200; on 5 November, 5400. (Photo File #HP 119.)

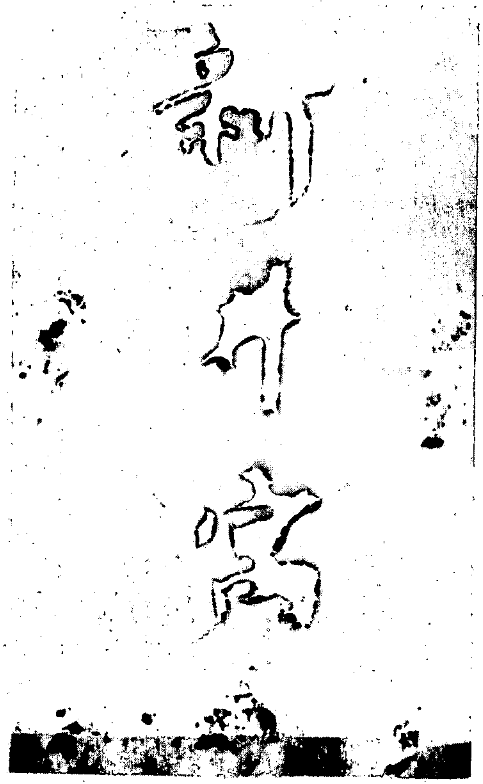


Fig. 50 (5H)--White Japanese rice paper with black characters charred through as a result of selective absorption of heat rays at 2300 meters. Japanese characters say "Arai House." This was the name plate of teacher Arai on the door of his classroom. (Photo File #HS 104.)

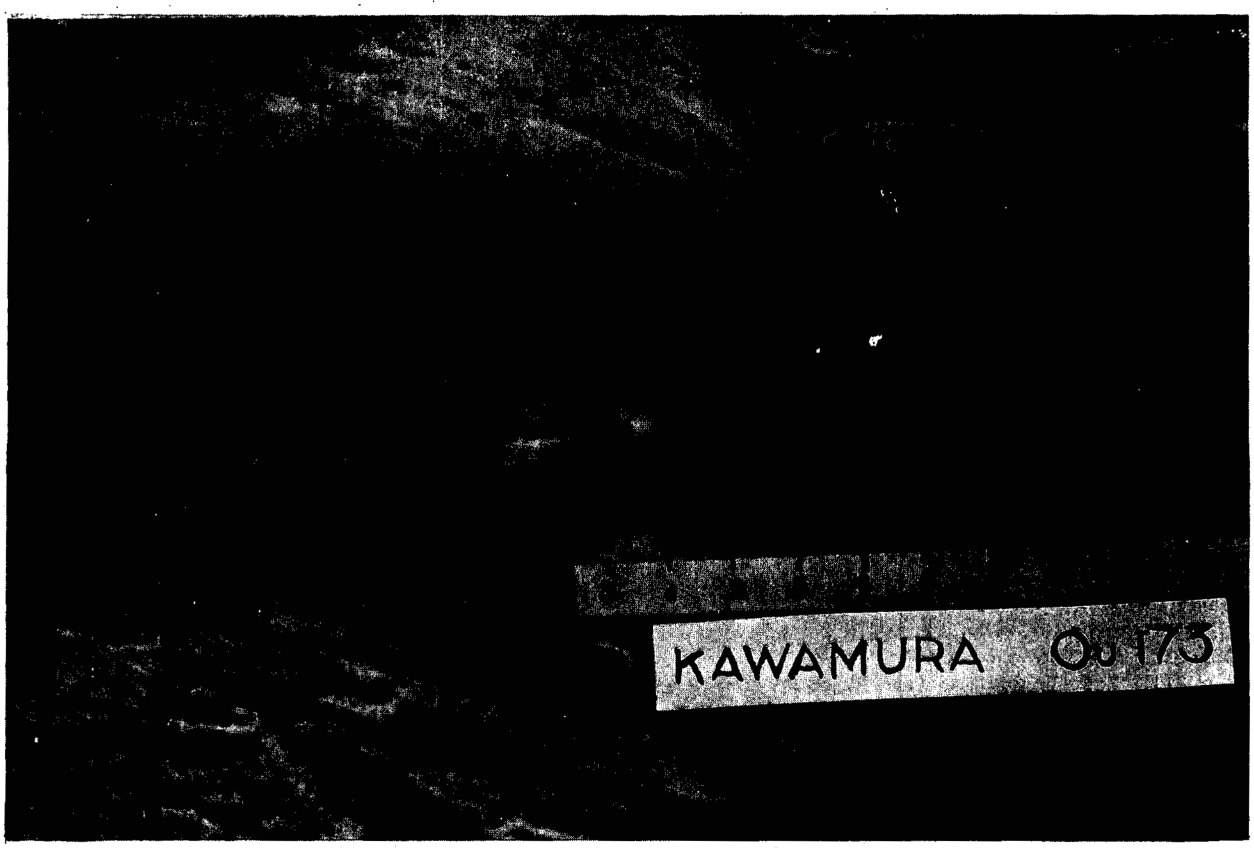


Fig. 51 (5H)--Kawamura. Case #S-9204-OU. Age 21. Female. 1600 meters. Rayon blouse. Action of heat rays. Charring and scorching of dark blue portions of the polka-dot pattern; minimal effect on the white background. Note that some of the polka-dots have been completely burned through. Others are partly scorched. The patient was also wearing a white slip and black mompe. Second degree burns were sustained of the chest and of the exposed face, right forearm, and hand. (Photo File #HS 101 (K).)

Fig. 52 (5H)--Matui. Case #S-8587-OU. Age 46. Female. 1700 meters. Rayon blouse. Action of heat rays--charring and scorching of the dark (blue-black) stripes; less effect on the light grey stripes. Folds of this garment on the side away from the bomb were in the path of the rays. On the near side, a portion of the cloth was charred. Patient suffered second and third degree burns of the chest, underlying the charred cloth where it was tightly stretched over the skin, and also of the exposed face, chest, arms, and neck. (Photo File #HS 100 (K).)

Fig. 53 (5H)--Shibata. Case #S-10034-N. Age 21. Female. 1800 meters. Cotton blouse. Pattern of red roses with green leaves on light pink background. Action of heat rays. Charring and scorching of red portions of the pattern. Less effect on the green and least effect on the white background. This probably results from darkness of shade, rather than color. Patient was also wearing a white, long slip and black and white mompe whose black parts were partly charred. Second and third degree burns occurred on the exposed parts of the left arm and beneath the charred portions of the cloth. These multiple small burns had become confluent on account of infection and had healed by the time the photograph of the blouse was made. There were burns also on the left thigh beneath the charred cloth and on the exposed portions of the left arm and left side of the face. (Photo File #HS 102a (K).)

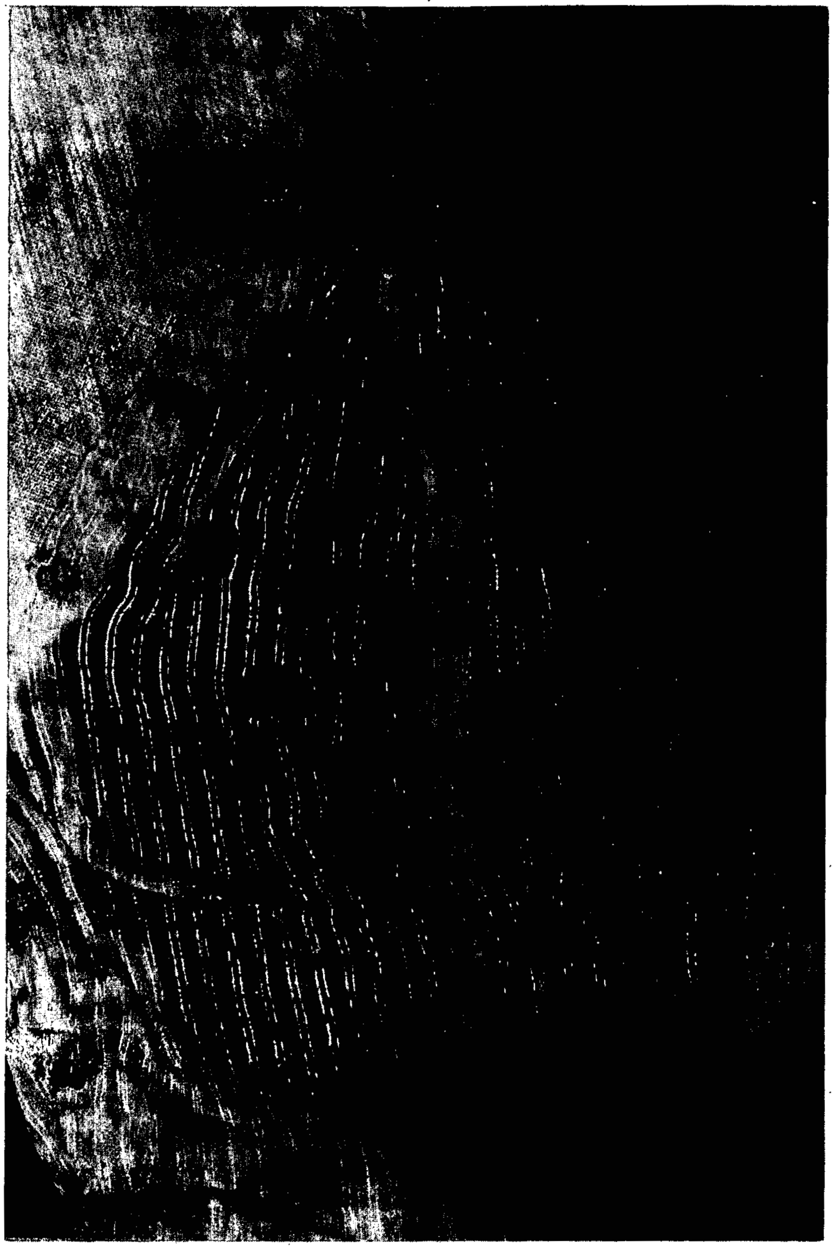


Fig. 54 (5H)--Shibata. Case #S-10034-N. Age 21. Female 1800 meters. Cotton blouse. Close-up of sleeve. (Photo File #HS 102b (K).)

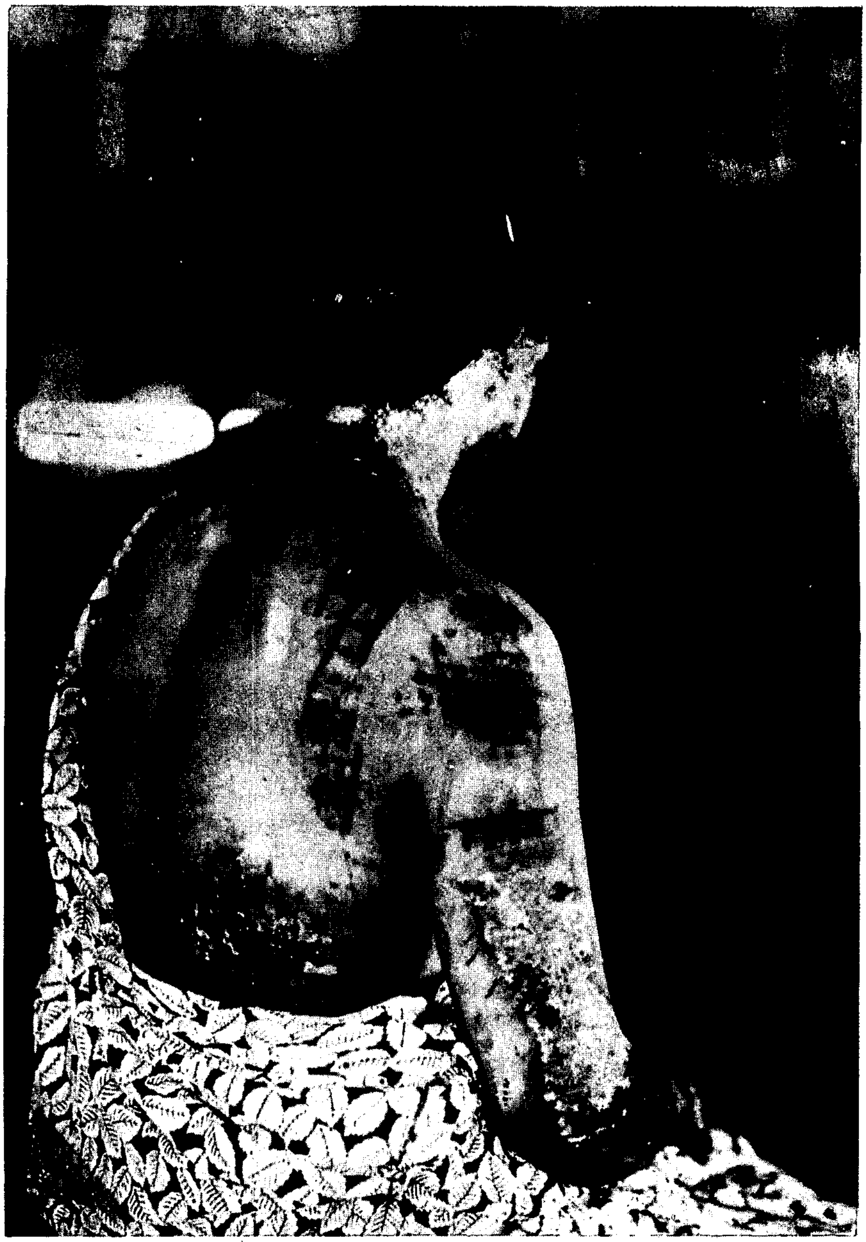


Fig. 55 (5H)--Ushio. Age ?. Female. "Flash burn" of back reproducing the pattern of the clothes. The darker portions of the material have absorbed more heat which has produced the linear burns. A portion of the actual garment the patient was wearing is shown in the next illustration. The darker material has become charred. Note that the burns of the exposed parts of the face and arm are much more severe than the skin beneath the cloth. The distance of this patient from the bomb is unknown. (Photo File #HP 138a.)

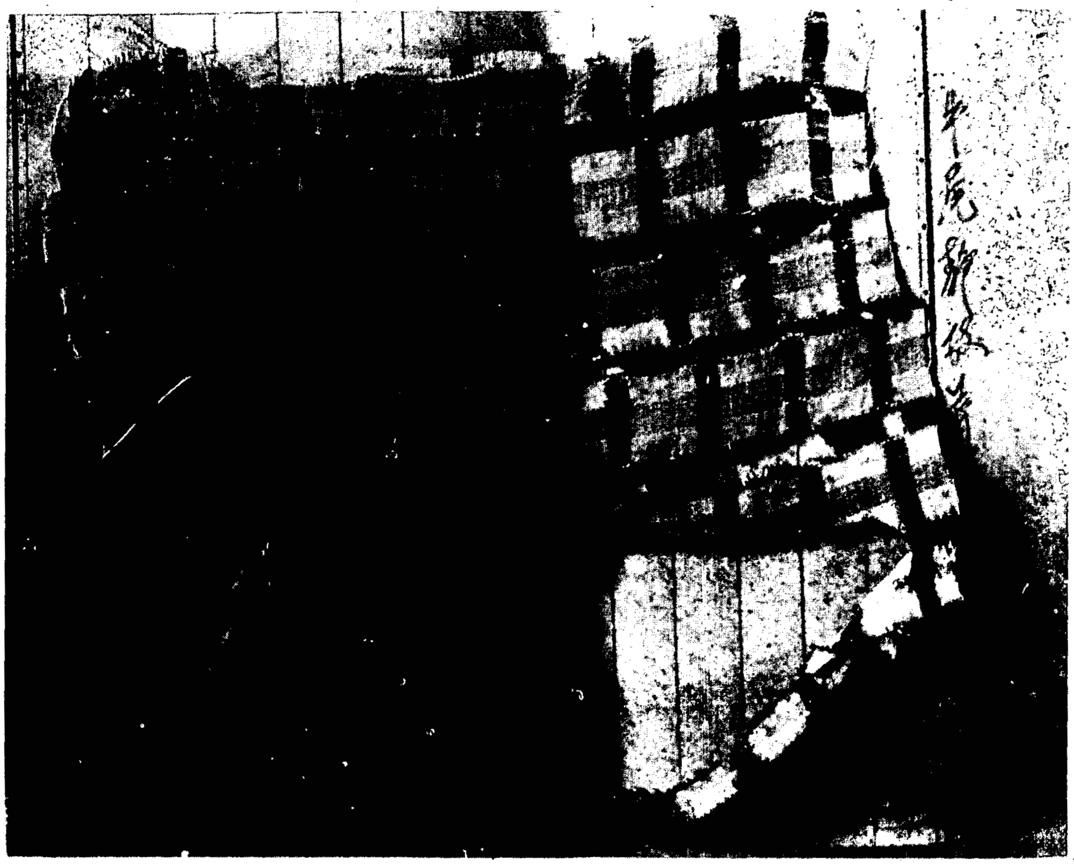


Fig. 56 (5H)--Ushio. Age ?. Female. A portion of the patient's blouse. The darkest parts of the pattern have become charred. Compare with preceding figure. (Photo File #HP 138b.)

Fig. 57 (5H)--Kitsunai. Case #0-8330-P. Age 20. Female. 1200 meters. Indoors on top floor of four-story building. "Flash burns" and healed lacerations. Patient clothed in the outer garment she was wearing at the time of the explosion. Charred portions of the kimono have fallen away. The lighter lozenges of the pattern are relatively resistant to the charring. Note that the burns have occurred where the clothing was tightest, with no particular relation to the intensity of the charring effect on the garment. This is obvious in the case of the loose sleeve over the mid-portion of the upper arm where charring has occurred, but where there are no burns of the skin. (Photo File #HP 108a (K).)

Fig. 58 (5H)--Kitsunai. Case #0-8330-P. Age 20. Female. 1200 meters. "Flash burns." Relation of burns to charred portions of clothing. Burns are most extensive where clothing was tightest (deltoid). Protection by strap of underclothing and by seam of the kimono over right shoulder. Intense pigmentation with little scarring. Note also multiple small healed lacerations produced by flying glass which penetrated the heavy garment. (Photo File #HP 108b (K).)

Fig. 59 (5H)--Autopsy Key #23. Satoi. Case #H-6176-U. Age 20. Male. 1000 meters. Died 31 August 1945. Epilation began 27 August, followed by petechiae and fever. WBC on 29 August = 3,330 and bleeding time = 28 minutes. WBC on 31 August = 45 and RBC = 2.30. (Photo File #HP 144.)

Fig. 60 (5H)--Hashimoto. Case #H-6135-U. Age 21. Male. 1000 meters. Indoors. Epilation appeared on 18 August. Gingival hemorrhages and petechiae of skin began on 29 August. Step-like rise of temperature beginning on 31 August. Necrotizing tonsillitis noted on 1 September. Delirium on 2 September and death on 3 September 1945. Laboratory data on 3 September; RBC 2.08. Hgb. 40%. WBC 1900. Platelets 10,400. Bleeding time, 46 minutes. Photo taken two hours before patient died. (Photo File #HP 135.)

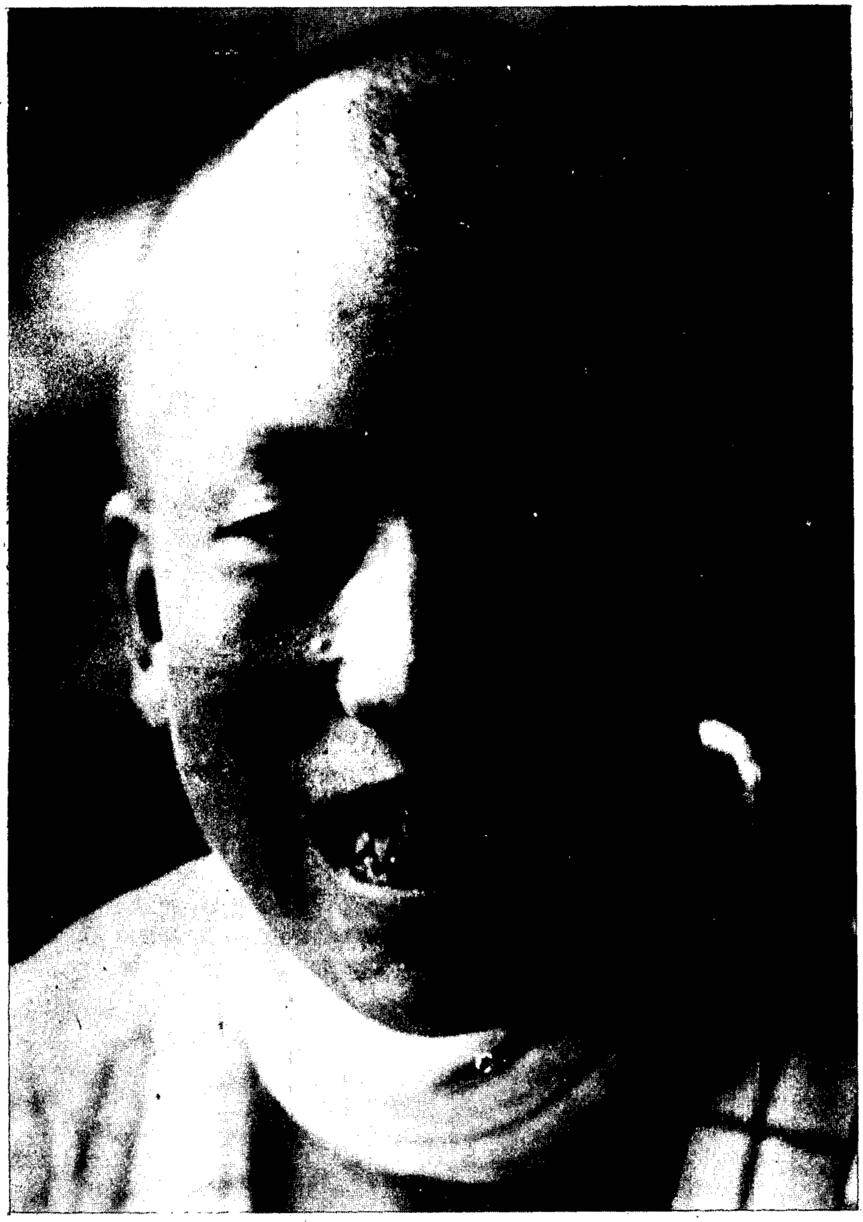


Fig. 61 (5H)--Ogami. Age ?. Male. 1000 meters. Necrotizing and hemorrhagic gingivitis, epilation, petechiae. (Photo File #HP 137.)

Fig. 62 (5H)--Okita. Male. Age 24. Case #H-6011-U. Healing gingivitis. There are some grey zones of scarring on the gums, which are still slightly swollen but no longer painful. Gingivitis began on 30 August, with pain and redness, but no bleeding until 11 September. Thereafter the lesion partly healed. Patient discharged from Ujina Hospital on 4 October. There were still some superficial ulcers of the buccal mucosa when he was seen at his home on 24 October. (Photo File #HP 124b (K).)

Fig. 63 (5H)--Autopsy Key #42. Moriseko. Case #H-6003-U, Age 33. Male. 1200 meters. Died 6 September 1945, 32 days. Necrosis and hemorrhage of tongue, petechiae of skin (1 day's duration). Epilation (11 days' duration). WBC on 27 August = 900. Platelets on 31 August = 22,900. (Photo File #HP 139.)

Fig. 64 (5H)--Maekawa. Case #H-6730-U. Age 25. Male. 600-700 meters. Indoors on second story of 2-story Japanese building. Nausea and vomiting began on day of bombing. Epilation began 20 August. WBC at end of August was 6400. Lowest recorded WBC 4300 on 24 October 1945. Slight downy regrowth of hair has already begun. Compare with Fig. 65. (Photo File #HP 105a.)

Fig. 65 (5H)--Maekawa. Case #H-6730-U. Age 25. Male. 600-700 meters. Epilation, partial regrowth of hair. Compare with photo of 25 October 1945 (Fig. 64). (Photo File #HP 105b.)

Fig. 66 (5H)--Kajiyama. Male. Age 29. 800 meters. Standing indoors in Japanese building. Epilation began on 26 August. The hair is downy. Note that there is loss of the hair upon the nape of the neck, as elsewhere. Nevertheless individual fine hairs are present everywhere. There are no coarse hairs as shown in the next photograph. The dark spots on the scalp are moles, not petechiae. (Photo File #HP 118a.)

Fig. 67 (5H)--Kajiyama. Case #H-6077-U. Age 29. Male. 800 meters. Standing indoors in Japanese building. Epilation began 26 August. Partial regrowth of hair. Compare with Fig. 66 (25 October 1945). The strong new hairs are widely and uniformly scattered over the head. (Photo File #HP 118b (K).)

Fig. 68 (5H)--Kadono. Case #S-7272-UJ. Age 14. Female. 900 meters. Sitting out of doors behind a stone gate or column 1.5 meters high. Epilation in 14 year old girl. Slight burns. She had the least radiation effect in her class of 45 girls, all but six of whom had died. WBC on 10 November were 8500. (Photo File #HP 116.)

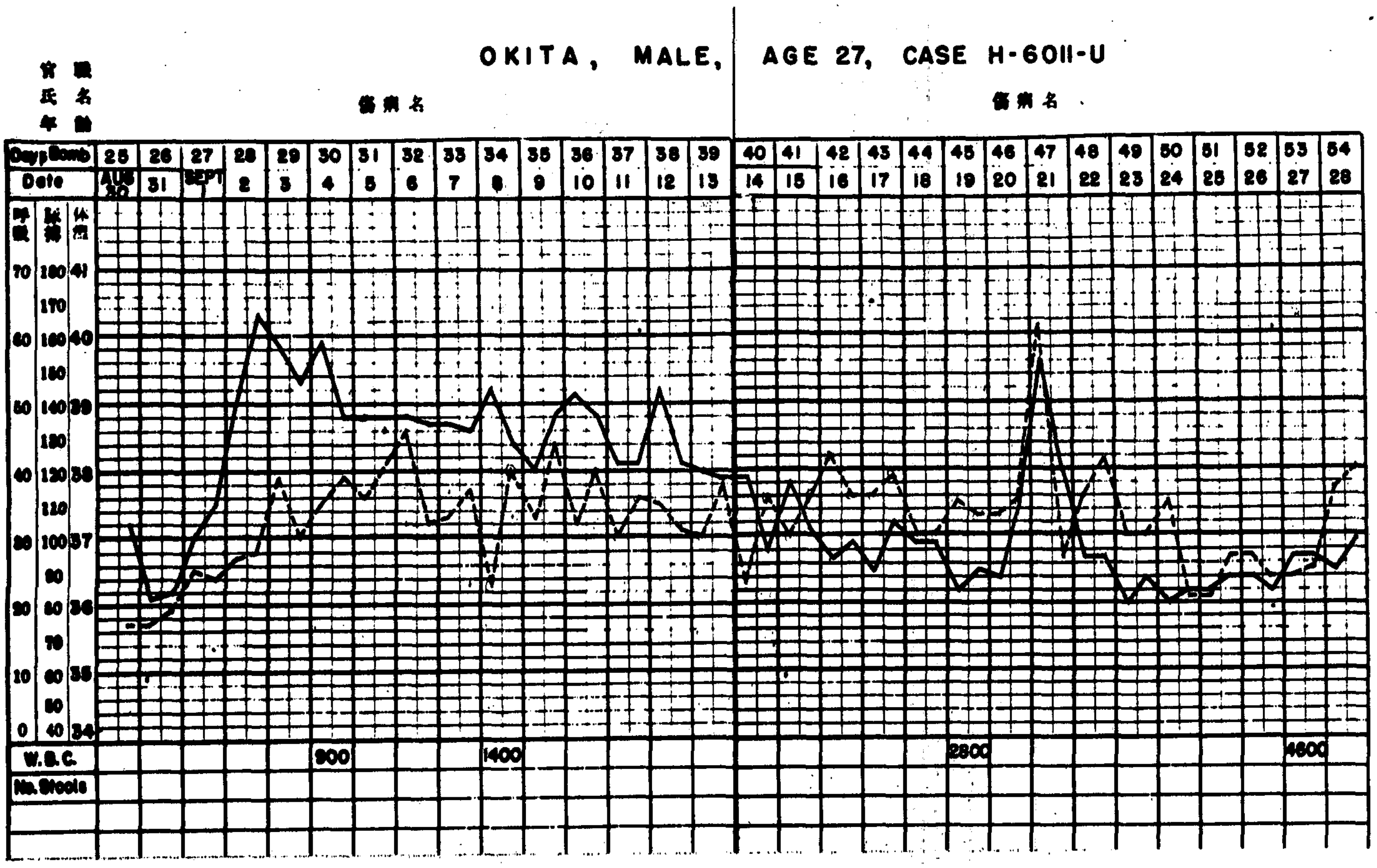


Fig. 69--(Photo File #HP 163.)

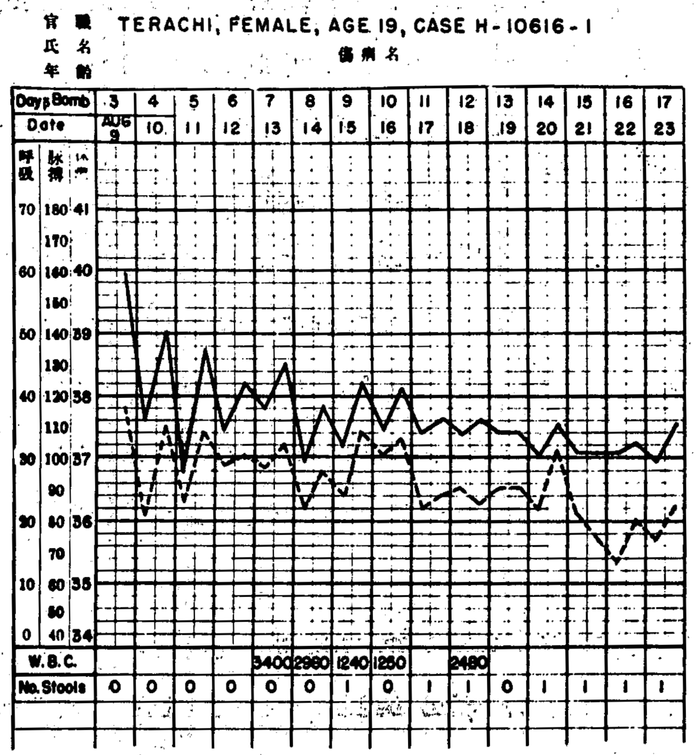


Fig. 70--(Photo File #HP 164.)

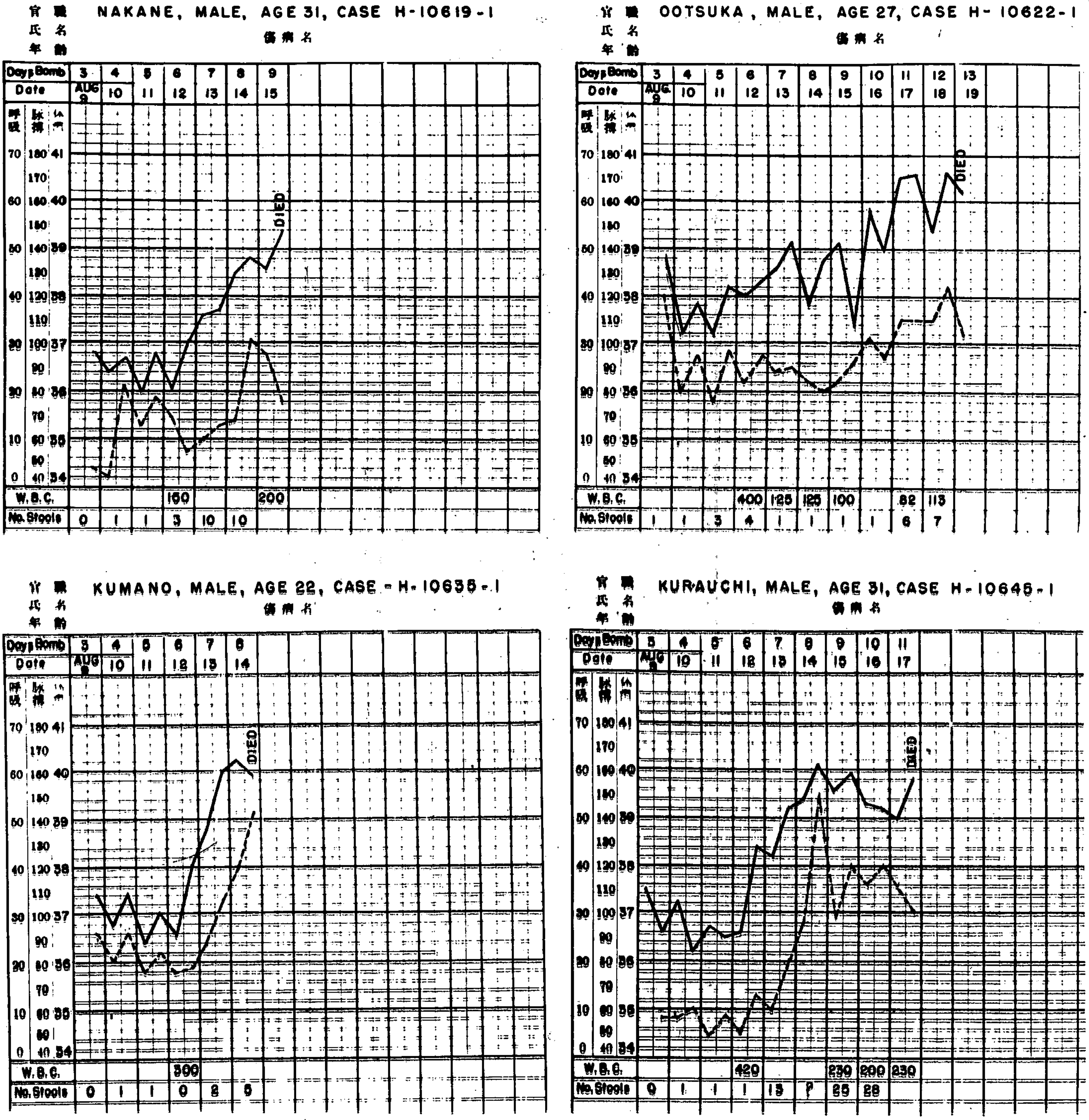


Fig. 71--(Photo File #HP 165.)

Section 5N

CLINICAL OBSERVATIONS IN NAGASAKI

Prepared by George V. LeRoy, Lt. Col., MC

Data Collected by Elbert DeCoursey, Col., MC, George V. LeRoy, Lt. Col., MC, Herman Tarnower, Major, MC, Samuel Berg, Major, MC, John J. Flick, Major, MC, Henry L. Barnett, Capt., MC, J. Thornton Perry, Capt., MC, and the Japanese Members of the Joint Commission Team in Nagasaki

1. General: A review of the types of injuries caused by the explosion of the atomic bomb in Nagasaki will be presented in this section. Particular attention will be directed to the novel type of casualty caused by the gamma rays emitted during the explosion. The emphasis, necessarily, must be placed on the diagnosis and the course of the syndrome of radiation injury, since the American Medical Officers did not arrive on the scene early enough to acquire personal experience in treatment.

The approach to the clinical discussion of the casualties will be primarily etiologic. It is known that the principle products of the explosion of an atomic bomb are:

a. Mechanical energy, or "blast".

b. Thermal energy, which as used here, includes both heat, and light. The normal components of sun-light; infra-red radiations, visible light; and ultra-violet radiations, were emitted in the atomic "explosion". The spectrum of the "light" that was produced is said to have resembled, if it was not identical with sun-light.

c. Energy of ionizing radiation, which as used here includes only neutrons and gamma rays. In the reactions attending nuclear fission, alpha and beta rays are also emitted; but the elevation of the airburst, and the physical properties of these particles are of such a nature that physicists are certain that neither reached the ground.

With this simple scheme it is possible to classify the casualties that occurred as:

a. Mechanical injuries.

b. Thermal injuries.

c. Radiation injuries.

In many of the patients any combination, or all three forms of injury were sustained. The primary type, or types, of injury were complicated in many instances by infections, the consequences of the loss of blood and the nutritional deficiencies that resulted from the altered economic conditions in a defeated country and a partially destroyed community. From a clinical standpoint it is neither possible, nor appropriate to attempt a separate consideration of the many complications that were observed. Accordingly, they will be treated as an inevitable feature of the various types of injury. These complications, and the coexistence of the three sorts of injury have made the presentation difficult; and it has seemed desirable to over-simplify the situation wherever possible.

At the time that the U. S. Army and U. S. Navy Medical Officers of the Joint Commission arrived in Nagasaki (30 September 1945) most of the severely injured patients had died, and the majority of those available for study were in some stage of convalescence. The clinical data for the period of illness prior to 30 September which was used in the preparation of this section was all obtained from the Japanese. Hospital and dispensary records, autopsy protocols, clinical reports, and conversations with the physicians who attended the casualties were the original sources of information. The questionnaires which were completed by the convalescents and by the patients who had recovered, were a useful source of data. These questionnaires, as well as ones which were trans-

cribed from satisfactory hospital records and ones completed for uninjured survivors, numbered about 6700. They were submitted to a thorough study in the Office of The Air Surgeon, U.S.A., the results of which are described in the statistical section. Excerpts from this study, the Japanese source material, and the personal observations of the writer and his colleagues form the basis for the synthesis which is offered. It has been a curious problem to describe injuries, and the natural history of a new disease, which one knows only in the convalescent stage, and by heresay, and from the examination of biopsy and autopsy material.

In the sections of the Report which dealt with the blood, the bone marrow, and the pathology of the syndrome of radiation injury, the material from the two cities was presented jointly. It was assumed, and there was good evidence in the material, that the effects of gamma rays on tissues were qualitatively similar in each group of casualties. In the course of studying the more copious and detailed material relating to the clinical features of the patients, there appeared to be some difference between the groups from each city. Rather than attempt a reconciliation of these differences, it seemed preferrable for the members of the Joint Commission who had worked in each city to present separately the clinical picture as it appeared to him and to his associates. The syndrome of injury due to total exposure of the human body to gamma rays is entirely novel. Since there is no earlier report in the medical literature of the course of individuals so exposed; and since it is problematic when or whether other cases of this type of injury will occur, it seems perfectly proper to present the available material in as great detail as possible.

2. Mechanical Injuries:

Incidence: The nature of the data available to the Joint Commission is

such that it is impossible to present precise information on any of the following points:

a. The total number of persons who received mechanical injuries.

b. The total number of persons whose only injury was due to mechanical causes.

c. The incidence of various sorts of mechanical injuries in either of the foregoing groups.

d. The percentage of deaths due solely to mechanical injuries.

e. The percentage of deaths in patients who had mechanical injuries, as well as injuries of other sorts.

This information could only have been obtained by the Japanese, since the majority of deaths occurred before the arrival of members of the U. S. Armed Forces. The remarkable disorganization of Japanese military and civilian medical personnel is reflected in their failure to collect adequate records of the causes or the circumstances of the deaths due to the atomic bombing.

The incidence of mechanical injury in the survivors in each ring zone is shown on figure 1. The data were obtained from the questionnaires, and the analysis of the relation of injury to location is presented in the Statistical Section. The data recorded on the questionnaires permitted a division of mechanical injuries into "severe" and "moderate" categories. The latter group consisted of single lesions, abrasions, contusions and fractures of small bones. The percentage of the "injured" survivors who had moderate mechanical injuries was 54.7%; and the incidence of severe injuries was 45.3%. This information is not very useful, and is of no help in clarifying any of the points referred to above.

The records of the Omura Naval Hospital provide the only complete breakdown of the diagnoses and the outcome of a large series of patients. The data from there, for the period 9 - 13 August, are shown in table 1. There is no group of radiation injuries for none were recognized at that time. The percentage of patients with mechanical injuries, 71.3%; and the percentage in whom this was the only injury, 57.6% should not be considered as certainly representative of the conditions that existed in Nagasaki. The patients in this series were evacuated by hospital train from the Urakami Station, close to the center of the explosion. It is not known whether there was any selection, or priority for evacuation; although the high fatality rate, 26%, would indicate that the severely injured must have been chosen.

The fatality rate, 10.9%, for patients who had only mechanical injuries was certainly too low. This rate applied only to patients who were able to escape from the debris of the damaged areas, and cannot include the ones who were trapped in the wreckage, or who died instantly from wounds.

In the report of the Commanding Officer of the 216 Field Hospital (temporary)(1), the percentage of patients with wounds was given as 70%. There are no records available to permit verification of this estimate. Among the injured survivors for whom questionnaires were completed, 64.7% had received mechanical injuries. These data are discussed in detail in the statistical secion

Although it is by no means conclusive evidence, the recurrence of the value, 65. - 70%, for the incidence of mechanical injuries in three large groups of patients, seems to suggest that this is probably the best estimate available.

(1) Appendix 4 N -(5)

TABLE 1

OMURA NAVAL HOSPITAL

DIAGNOSIS AND OUTCOME OF PATIENTS

ADMITTED BETWEEN 9 - 13 AUGUST

DIAGNOSIS	ADMISSIONS NO.	ADMISSIONS PER CENT OF ALL ADMISSIONS	DEATHS NO.	DEATHS PER CENT WHO DIED	DEATHS PER CENT OF ALL DEATHS
1. Wounds only	356	57.6	39	10.9	24.4
2. Burns, only	177	28.6	89	50.3	55.6
3. Wounds and Burns	85	13.7	32	37.7	20.0
Totals	618	100.0	160	26.0	100.0
All Wounds (1 plus 3)	441	71.3			
All Burns (2 plus 3)	262	42.4			

It is unfortunate that the Report of a casualty study is unable to provide accurate data on the incidence and the approximate fatality rate of each type of injury.

Etiologic Factors: In a discussion of the type of injuries resulting from the explosion of substances like TNT, or the usual missiles of war, it is customary to subdivide them into five categories as follows:

a) Primary, or air blast injuries.- The single type of lesion uniformly present is "bruising and rupture of the lungs".(1) Other lesions occur in the viscera, the central nervous system, and the auditory apparatus.

b) Primary, or flash burns.

c) Secondary injuries, due to portions of the casing which contained the explosive.

d) Secondary injuries due to fragments of stone, buildings, vehicles, etc. violently displaced by the explosion. This category includes injuries caused by the collapse of buildings, etc.

e) Secondary injuries, incurred when the victim is violently displaced, and strikes the ground, buildings, and other objects.

In the case of an ordinary explosive, like a large aerial bomb, the blast consists of two phases: a positive, or compression phase, with a duration of the order of 0.006 seconds; and a negative, or suction phase, with a duration of the order of 0.03 seconds. The blast wave that is formed is a very fast, intense sound wave, which quickly slows down to the speed of sound. Its intensity decreases as the square of the distance. The peak pressures which can be measured may be of the order of 50 or more atmospheres.(2).

(1) Hooker, D.R., "Physiological Effects of Air Concussion",-Am. J. Physiol. 67: 219-274, Jan. 1924.
(2) Corey, E. L. "Medical Aspects of Blast", U.S. Naval Med. Bull. 46: 626, 1946.

The pressure in the negative phase can never exceed one atmosphere. Immediately surrounding the explosion there is a "zone of brisance" whose size varies with the amount and character of the change. Inside this zone, people, buildings, instruments, etc. are disintegrated and the pressures occurring there can only be a matter of conjecture. Beyond (and including) the zone of brisance, there is a region in which the heat of the explosion causes flash burns. In the case of a charge of approximately 1000 lbs of TNT, the "burn zone" has a radius of the order of 80-100 feet. Patients who are outside the region where burns can be received seldom have air blast injuries. The majority of the wounds due to high explosives are secondary injuries (c, d and e) caused by secondary projectiles, the violent displacement of the victim, or collapsing buildings. This brief review of the medical aspects of ordinary explosions has been presented as a preliminary to the discussion of types of mechanical injuries that were caused by the atomic bomb.

Until the results of the first atomic bomb test at Bikini are available it is impossible to quote accurate figures for the peak blast pressure, the duration of the blast, or the amount of heat evolved. Some use can be made of the calculations by Japanese physicists who visited the two cities. The duration of the blast is given variously as from 0.01 to 0.1 seconds. The peak pressure on the ground directly beneath the explosion, and at various distances from the point were calculated by Prof. Tanaka of the Nishina laboratory and are shown in Table 2.

The ability of pressure of this magnitude to cause air blast injury of various types is uncertain. It is said (1) that at least 15 atmospheres of

(1) Personal communication, Prof. S. Zuckerman, RAF explosive expert.

over-pressure received face on, are required to produce typical blast injuries to the lungs. It is also said that more than this amount (1) is required to cause rupture of the intestines. No reliable case reports were obtained in Nagasaki of patients with pulmonary or visceral injuries attributable to air blast. One eye witness report has been widely circulated and exaggerated, to the effect that some of the dead at an air raid shelter 300 meters from the center, had ruptured eyeballs; and that their abdomens were split open and the viscera exposed. A member of the Joint Commission interrogated survivors who had been inside the air raid shelter when these casualties were reported. He verified the presence of the dead people, but flatly denied the reported findings.

TABLE 2 A

BLAST PRESSURE GENERATED
By
THE ATOMIC BOMB - NAGASAKI

(1.0 Kg/cm^2 equals one atmosphere)

LOCATION	PRESSURE
Below the bomb	6 - 8 Kg/cm^2
400 meters from center:	2.0 Kg/cm^2
500 meters from center:	1.0 Kg/cm^2
1000 meters from center:	0.130 Kg/cm^2

The occurrence of ruptured ear drums was the subject of investigation because of interest in the amount of over-pressure generated by the bomb. In the early medical reports from Nagasaki there are no specific data, but one frequently encounters in Japanese reports the statement that there were only a "few patients with ruptured tympani". An otologist from Tokyo Imperial

(1) Corey, loc. cit. The reference was to pressures of immersion blast required to rupture intestines: the values found were in excess of 250 lbs. per sq. inch (16 plus, atmospheres)

University, Dr. Kashiwado,[1] studied the problem among survivors, during October with the following results. (See table 3B). It is true that this was not a truly representative sample, but it is the best data available on the incidence of the lesion. There was no way to determine whether the ruptures observed were due to the atomic bomb or to the detonation of explosive material of one sort or another.

TABLE 3 B

NAGASAKI

INCIDENCE OF RUPTURED EAR DRUMS IN SURVIVORS

	DISTANCE FROM CENTER, METERS			
	0-500	500-1000	1000 plus	Total
With ruptured drums	4	10	0	
Without ruptured drums	40	115	29	
Total cases examined	44	125	29	198
Per cent with ruptured drums	9.0	8.0	0	7.0

The amount of over-pressure necessary to rupture the living human ear drum is not definitely known, but the time-honored figure of 7 pounds per square inch (0.5 kg/cm^2 would appear fairly accurate, at least as regards blast in air". (2) In practice many war ships have lines painted on the deck around gun positions to indicate the distance to which this degree of pressure occurs. In the report rendered by Kashiwado, he cited the work of Zalewski (3) on the ear drums of cadavers. Hydrostatic pressures in excess of 2 atmospheres ruptured 24% of the

(1) Appendix 4 N (28)
(2) Corey, loc. cit.
(3) Zeitschr f. Ohren. 25: 109, 1906

drums; between 1 and 2 atmospheres ruptured 65.7% of the drums; pressures of various amounts less than 1 atmosphere ruptured only 10%; and the least pressure which was effective was 0.38 Kg/cm^2. The correlation of these data with Kashiwado's findings are surprisingly good.

It appears from the foregoing that the amount of over-pressure which accompanied the blast of the exploding atomic bomb caused the rupture of ear drums in some patients. The apparent absence of other clinical evidence of air blast injury is in accord with the pressure changes cited by the Japanese physicists.

Just as in the case of other high explosive weapons, the majority of the casualties that occurred in Nagasaki were secondary. No instance was found by the Joint Commission, and none was reported by the Japanese, where injury was caused by fragments of the metallic housing of the bomb. According to one of the physicists (1) the heat of the fission reaction was so intense that all the metal of the bomb casing was vaporized at once.

The mechanical injuries that occurred were secondary injuries of the last two types due to flying debris, falling buildings, etc., or due to violent displacement of the patient with wounds resulting from striking the ground or other solid objects. Of the latter type there is little precise information. Many of the eye witnesses described being thrown to the ground or being blown across a room. However, among the questionnaires collected from 3800 injured survivors, there were very few in whom the wounds attributed to violent displacement were more serious than abrasions or contusions.(2) None of the patients with fractures attributed them to the

(1) Personal communication, Prof. V. F. Weiskopf, Massachusetts Institute of Technology.

(2) See Appendix 3N

results of being thrown about by the blast.

Since nearly all the mechanical injuries were due to the collapse of or damage to the various types of buildings, it is of interest to learn the degree of violence with which the damage occurred. The contemporary accounts provide no information at all. There is no record of large portions of buildings or trees, or pieces of machinery being blown long distances as is the case with heavy explosions, like those of ammunition ships. The engineers with the British Mission to Japan (1) stated that most of the debris from a demolished building could be recognized close to the original site; and that there was no sign that sizeable fragments were blown any great distance. One bit of tangible evidence that the Joint Commission discovered that demonstrates the violent displacement of fragments of one sort is illustrated in Figure 2. The missile shown is a piece of wood which was blown into the boards of a fence. The fact that this stick was not there prior to the atomic bomb explosion is indicated by the absence of a shadow similar to those cast by the weeds which grew between the fence and the burst. It is apparent that if small pieces of wood were hurled about with sufficient force to penetrate a board, they would also be capable of inflicting serious injury to a person.

It is as difficult to enumerate the agents which caused the mechanical injuries as it was to determine the number and variety of them. The reader will do well to consider that anything which entered into the construction of any of the buildings participated in the production of the injuries. Apparently the most numerous type of injuries was due to flying fragments of

(1) Report of the British Mission to Japan, War Office, classified.

glass. In some of the patients, the number of lacerations due to this cause was very great and in spite of the small size of the individual wound, their depth and multiplicity created a serious condition. The role of the various types of building in the production of casualties can be shown in pictures better than it can be described. See Figures 3,4,5,6,7,8,9,10. The graph in Figure 11 shows the incidence of mechanical injuries in people who were inside buildings, compared with the incidence in those who were outdoors. This subject is presented in detail in Section 9. The tabulations of injuries reported by the survivor group do not give a true picture of the situation, for it is certain that the most severely injured had died long before the questionnaire study was begun.

In general it may be said that the type of mechanical injuries incurred by the victims of the atomic bomb depended to a large degree on the sort of buildings which they occupied. The fatality rate and the casualty rate for different types of buildings totally demolished by high explosives has been determined in England.(1) It is unfortunate that the data obtained in Japan is not sufficiently detailed to permit of similar calculations.

There is one aspect of the mechanical injuries which is not summarized in the statistical section but which deserves general comment: namely the role of wound-infection in increasing the disability and the fatality rate. The disorganized conditions in the city, and the destruction of the Hospital, and the death of perhaps one-half the medical personnel, plus the deficiency of sulfonamides contributed to the development of a situation where nearly every wound became infected. In the hospitals that were visited, screening of the wards and dressing rooms was not practiced, and although the medical

(1) Report of HE incidents, Classified, RAF Reports.

attendants manipulated the wounds and dressings in a cleanly manner, the unhygienic environment was apparent. Japanese physicians told the members of the Joint Commission that wound suppuration was very frequent; and in the patients with radiation injury also, it was nearly universal. The effect on the death rate is not ascertainable. An interesting fact was the very low incidence of tetanus in spite of the inability of the doctors to administer anti-tetanic serum. At the Omura Naval Hospital, there were only 3 cases of tetanus among 758 patients who were treated. At the 216 Field Hospital (temporary) in Nagasaki City there were 4 cases among the 350 patients admitted.

SUMMARY

1. The extent to which mechanical injuries contributed to the total killed rate and the total casualty rate cannot be determined accurately. The best estimate possible is that 64-70% of the casualties were mechanical injuries.

2. Over-pressure due to air blast (or concussion) was not an important cause of injury. The maximum peak pressure was of the order of 8 atmospheres, an amount which is capable of causing little damage other than ruptured ear drums.

3. The bulk of the mechanical injuries were of a secondary type, and of these the majority were due to the demolition and damage of buildings.

4. In general, the nature of an injury was determined by the type of building responsible.

5. The commonest type of injury was laceration by small fragments of glass.

6. The morbidity and the mortality due to the wounds was undoubtedly increased by the very high incidence of wound infection that occurred.

(3) Thermal injuries.

Incidence: The type of data available to the Joint Commission was such that it is impossible to present precise information on any of the following points:

(a) The total number of persons who received thermal injuries.

(b) The total number of persons whose only injury was a burn.

(c) The incidence of flash burns and flame burns in each of the foregoing groups.

(d) The incidence of first, second and third degree burns of either type, in each of the foregoing groups.

(e) The percentage of deaths due solely to one or the other, or to both types of burns.

(f) The percentage of deaths of patients who had burns, as well as other sorts of injuries.

(g) The percentage of burned patients who had radiation injury, and the fatality rate of this group.

The failure of the Report to provide any of this information with a satisfactory degree of accuracy is a serious defect, which must be attributed to the inadequate records that were kept by the Japanese after the bombing. It would be possible to offer the same sort of rough estimate for the total number of burns, as was done in the case of mechanical injuries, but the high mortality rate of burned patients during the first few weeks, and, in particular, the high mortality among the most exposed groups, makes such a calculation very unreliable.

The thermal injuries may be divided into two categories: first, those caused directly by the heat generated by the bombs, <u>the flash burns;</u> second,

those caused by the fires that started in the damaged buildings after the bombing. The flame burns. The questionnaires collected by the Joint Commission were completed in such a manner that it was not always possible to determine which source of heat produced the burn. In 970 records, the type of burn was adequately described. Of those, 96% were flash burns; and 4% were flame burns. In 348 of the records the etiology of the burn could not be determined. There was no reason to think the latter group differed from the others, so that for practical purposes, all the burns were considered flash burns. Of the flash burns, 59.8% were described as moderate and 40.2% as severe. Since the entire group were survivors, this breakdown has little meaning.

Certain data were collected at the Omura Naval Hospital which give some statistical information on the burns. The original data were not available for verification by the Joint Commission, and the figures are offered with reservation. Of the 758 casualties treated there, over a period of 7 weeks, 431, or 57% were burned. In Table 2 is shown the relevant data on this group, reported by Surgeon Lt. Comdr. N. Fukuhara. Table 1, page 6, contained the diagnosis and the outcome of the 618 patients at Omura Naval Hospital who were evacuated by hospital train during the first 5 days after the bombing. It will be seen that 42% of those were burned, while when the total experience of the hospital is reported 57% of the patients were burned. Comparing these tables it is seen that after 13 August, 140 more casualties were admitted, while the total number of burn cases increased by 169. These internal inconsistencies in Japanese reports were common, and cause one to view all related data skeptically. The figures in Table 1 were verified from translated records; those in Table 2 were not.

TABLE 2

REPORT ON BURNS

OMURA NAVAL HOSPITAL

1.	Location at time of injury:	a) Outdoors	- 81%
		b) Indoors	- 19%
2.	Cause of Burn	a) Flash	- 97%
		b) Flame	- 3%
3.	Distribution of Burn.	a) Exposed skin, only	- 37%
		b) Exposed skin, plus that covered by clothing.	- 63%

The high fatality rate of the burned patients reduced the number available for interrogation by the American doctors to such an extent that any information obtained after 1 October cannot be considered as typical of the conditions that existed at the time of the bombing. The experience at the Omura Naval Hospital (verified records only) with burns can be summarized as follows:

(1) 42.4% of all casualties were burned.

(2) 28.6% of all casualties had only burns.

(3) 46.0% of all burned patients died.

(4) 50.3% of patients with only burns died.

(5) 75.6% of the dead patients were burned.

The gist of this summary may be stated briefly as follows: 42% of all the casualties; and 76% of all the deaths were burned. With the data which is available it is not possible to give a better estimate of the extent to which burns contributed to the casualty rate and the mortality rate of the people exposed to the atomic bomb. This rather complicated group of figures can be reduced to

a simple basis of the expected diagnosis and outcome of 100 casualties who were evacuated from the city, as shown in Table 3.

TABLE 3

EXPECTED DIAGNOSIS AND OUTCOME PER 100 CASUALTIES

Casualties, all types	100
Burned (with or without other injuries)	42
Not burned (but with other injuries)	58
Died with burns (with or without other injuries)	19
Died, not burned	6
Died, all causes	25
Recovered	75

At the 216th Field Hospital (temporary) (1) in Nagasaki, 65% of the patients were burned. Of these, 90% were reported to have been second degree burns, but there are no records available to permit verification of these estimates which were contained in a report of the commanding officer to the Prefect of Nagasaki. There was no data from this hospital on the mortality rate among burned patients.

Among the group of survivors for whom questionnaires were completed, burns were reported by 34.8%.

These three percentages: 42%, 65% and 34% are the best estimates that are available of the general incidence of burns among the casualties. In the statistical section the data on burns in relation to distance and protective factors are considered in detail.

(1) Appendix 4 N (5)

It can be assumed that within the effective range of the heat from the bomb, all persons whose position was in a line-of-sight relation to the airburst were burned. As a corollary, those who were outdoors within, say, 3500 meters of the bomb and received no burns were protected by some structure which intercepted the burning rays. People inside buildings were only burned when the rays could reach them through doors, windows, etc. Of a group of people "inside" the Ohashi Arms Works, 34 of 210, or 14% were burned. Of another group "inside" the Morimachi Arms Works, 12 of 101, or 12% were burned. There is a general agreement among the available figures on the incidence of flash burns in people who were indoors. The data from Omura Naval Hospital (Table 2) showed that 19% of the burned patients were indoors; and in the questionnaire study, Section 9, the incidence of burns among people who were inside buildings was approximately 12%. A comparison of the incidence of flash burns in people who were outdoors, and those who were inside wooden buildings is shown in Figure 13. The curves for the incidence of burns by ring zones have a curious shape. In the survivor group the percentage of burns is less in ring zones 1 and 2 where it is known that the heat was greatest. The explanation is simple: close to the center the burns that occurred were more serious, and the case-fatality rate was correspondingly greater, which means that the number of survivors who could be studied by the questionnaire method was less. There does not appear to have been any persons who were actually in the open, closer than 1500 meters, who were not burned. At distances closer than this, in addition to severe burns, the patients

received harmful amounts of ionizing radiation. The complication of a severe burn by radiation injury was unquestionably a serious matter, and it is not surprising that so few of these survived.

Etiologic factors: The flame burns that patients received from burning debris, or inside bunning buildings, or from burning clothing were not unique, and need not be considered in the present discussion. There seems to be no reason to doubt that certain kinds of clothing did burst into flames because of the flash of heat, and there is evidence that this increased the severity of the burns.

The term "flash burn" is applied customarily to the lesions caused by brief or instantaneous exposure to a source of heat. Burns of this type are generally associated with explosions, and are especially frequent in warfare. The majority of flash burns display shadow effects in the sense that only the portions of the body directly exposed to the source of heat are burned, and the parts which are "in the shade" of any heat-impervious structure are uninjured. Because of the brief duration of the heat, clothing is protective to an extent which depends on the heat-intensity and the quality of the material. During World War II naval surgeons developed an anti-flash cream" application of which was sufficient to protect the skin from the effects of the heat from the muzzle-blasts and from exploding shells and aerial bombs. The burns that occurred in Nagasaki had the appearance of typical flash burns, and showed characteristically the shadow effect. Theheat -intensity at some distance, say 2000 meters,

from the source was such that burns were inflicted on skin protected by clothing, and on skin over which the clothing was tightly drawn.

The etiologic factors responsible for the burns caused by the atomic bomb are different and more complex than the simple exothermic chemical reaction of high explosives. The products of the atomic explosion which could cause burns are the following:

a) Heat, in the chemical and mechanical sense, which resulted from the conversion of the energy liberated when the plutonium nuclei underwent fission.

b) Radiant heat which includes infra red rays, and visible light rays, emitted by the incandescent mass of air, fission products and vaporized metal from the casing immediately surrounding the exploding bomb.

c) Ultra violet rays, (from the same source as b)

In Japan, no direct physical measurements were made of the intensities of any of these three factors. It is likely that such measurements were made during the explosion of the plutonium bomb at Bikini, but at present they are not available. The theoretical estimates of the fraction of the total energy which was transformed into heat has not been announced. Certain estimates of the heat delivered to human bodies are available and will be presented below. The consensus among physicists is that the majority of the burns were caused by radiant heat. The statement was made by one of them (1) that the heating of the air (i.e. conducted heat from the exploding bomb) was not a serious problem, and that in Japan the superheated air adjacent to the bomb should not have touched the ground, since the radius of the mass probably did not exceed 300 meters. A number of the eye witness accounts

(1) Personal communication, Prof. V. F. Weiskopf.

describe the sensation of a warm or hot wind blowing against their skin, but it is difficult to know how to interpret this type of subjective information. The radiant heat (and light) which caused the flash burns was not all infra red, but included the entire visible spectrum. The physical characteristics of this sort of heat are that:

a) It is not absorbed by air.

b) The dissipation of it follows the inverse-square law.

c) It is absorbed by dark-colored substances and reflected by light-colored ones.

Ultra-violet rays were emitted by the explosion, and in the earlier test at Alamagordo, it was found by spectral measurements that the amount was equivalent to that in sunlight. This type of radiation is absorbed to a considerable extent by air, and in view of the brief duration of the emission, it was the opinion of the physicists that the amount reaching people at distances where the heat was not instantly lethal (500-700 meters), was not sufficient to burn the skin. Some of the early Japanese clinical reports mention the recurrence of conjunctivitis and keratitis during the first week after the bomb. This condition was said to have recovered spontaneously, and could have been an actinic keratitis. The extent to which the ultra-violet rays were responsible for the skin pigmentation is not known.

In a consideration of the flash-type of burn, it is desirable to know the time intensity curve for the heat causing the burns. No measurements were made in Nagasaki, but certain estimates were prepared from the experimental and theoretical data by a physicist who worked on the development of the bomb. (1). The following assumptions were made:

(1) Personal communication, Prof. V. F. Weiskopf

1) The duration of the heat flux was 1.0 seconds.

2) The human skin acts as a black body with respect to radiant heat.

3) The heat capacity of skin and tissue is equivalent to that of water.

4) The heat conductivity of skin and tissue is equivalent to that of water.

5) The amount of heat required to destroy tissue is the amount required to raise the temperature from 30° to 100° C. during one second.

On the basis of these assumptions the amount of heat delivered to a body at various distances from the bomb, and the depth to which the destructive action (i.e. the raising of tissue temperature to 100°C) extended were calculated. The minimum and maximum limits that could be predicted are shown. The range is based on the assumption that the maximum amount of radiant heat may have been 50% greater than the amount used for the minimum value.

TABLE 4

DISTANCE AND HEAT EFFECT: TIME: 1 SECOND

DISTANCE FROM BOMB, METERS*	TOTAL HEAT DELIVERED CAL/ cm^2		DEPTH TO WHICH TISSUE WAS HEATED TO 100°C. mm	
	MAXIMUM	MINIMUM	MAXIMUM	MINIMUM
500	150	100	21.0	14.0
1000	37	25	4.5	3.0
2000	9	6	1.4	0.9
3000	4	3	0.6	0.4
4000	2.4	1.6	0.3	0.2

*This is the linear distance from airburst to the subject.

There is some question of the actual duration of the heat flux, but the value shown in the table can be adjusted easily in the appropriate direction. By the application of the inverse-square law, the approximate calories/ cm^2 delivered, or the depth of burn, at any distance from the bomb can be estimated. This is a very significant table for it shows that on bare skin, a third degree burn 2.1 to 1.4 cm in depth would be received by persons 500 meters distant. Assuming that the elevation of the airburst was 500 meters (this is the Japanese estimate) people directly beneath it obviously received terrible burns, which were undoubtedly instantly fatal. At a distance of 500 meters from the center, or approximately 700 meters from the air burst, the heat delivered to the skin would have been 75 to 50 calories/ cm^2 and the depth of the 3rd degree burn 10.5 to 7 mm. The people in the yard of the Chinzei Middle School were at such a distance, and nearly all were burned to death instantly in spite of the fact that they were probably clothed.

The significance of the data in Table 4 is difficult to appreciate without some knowledge of the type of burn that could result from the amounts of heat delivered to skin at distances in excess of 2000 meters, namely 9 cal. / cm^2/ sec. or less. Information on this subject is available in a study of experimental human burns by Ashe and Roberts (1). Using a stream of air flowing at a rate of 6 liters per minute, and heated to temperatures varying between 100° C and 500° C, they investigated the time-temperature relationship for the production of first and second degree burns. This relationship was found to be exponential. The data from their graphs has been rearranged, and is shown in Tables 5 and 6.

(1) Ashe, W.F., Jr., and Roberts, L.B., "Experimental Human Burns" War Med. 7: 82-83, 1945.
(From the Armored Medical Research Laboratory, Fort Knox, Ky.)

TABLE 5

EXPERIMENTAL HUMAN BURNS

Rate of Air-flow: 6 liters / minute

TEMPERATURE OF AIR, MEASURED AT SKIN: DEGREES C	HEAT DELIVERED TO SKIN CALORIES/CM^2/SECOND
100	1.8
200	4.0
300	6.2
400	8.3
500	10.7

TABLE 6

EXPERIMENTAL HUMAN BURNS

TIME- TEMPERATURE RELATIONSHIP

RATE OF HEAT DELIVERY TO SKIN : CALORIES/cm^2/ SEC.	TIME IN SECONDS REQUIRED TO PRODUCE FIRST DEGREE BURN	SECOND DEGREE BURN
1.8	4.0 - 6.0	8.0 - 10.0
4.0	1.0 - 2.0	2.0 - 3.0
6.2	0.5 - 0.7	0.7 - 1.5
8.3	0.15 - 0.25	0.3 - 0.7
10.7	0.06 - 0.15	0.2 - 0.3

Granting the validity of the assumptions and of the data in Tables 4, 5 and 6, it can be seen that second degree burns were a theoretical possibility at distances as great as 2500 meters from the bomb. First degree burns would be possible at distances as great as 3000 meters. Actually, the estimates of the physicist were conservative, for the study of the

questionnaire revealed that burns (presumably first degree) were received by patients in Ring 6, 3000 - 4000 meters from the center.[1]

The foregoing data may be combined with some of the observations made by a Japanese member of the Joint Commission (2) in the Omura Naval Hospital in October. Patients recovering from severe burns were questioned, and it was found that they could be divided into 3 groups on the basis of the appearance of their burns on the day of the bombing. In some there was exfoliation, in others there was vesicle formation, and in others, both exfoliation and vesicle formation occurred immediately. There were 44 patients whose location was definitely known. and whose records described the state of their burns on admission during the nights of 9-10 August. The data for these patients, as well as the theoretical amount of heat delivered is combined in Table 7.

TABLE 7

OBSERVATION ON PATIENTS WITH SECOND DEGREE BURNS
OMURA NAVAL HOSPITAL

DISTANCE FROM BOMB, METERS	RANGE OF HEAT DELIVERED* Cal./cm²/sec.	CONDITION OF SKIN AT ADMISSION-9-10 AUGUST.		
		EXFOLIATION	EXFOLIATION & VESICLES	VESICLES ONLY
Less than 1000	150-25	7	2	1
1100 - 1500	37 - 11	6	2	3
1600-2000	16 - 6	6	2	5
2100-2500	9 - 4	3	3	4

*See Table 4. These values are for linear distance from airburst to patient. The amounts of heat would be somewhat less if based on distance from center on the ground to the patient.

(1) Examples of severe burns at known long distances are: Case #408-2800 meters; #3152-2800 meters; #3185-2900 meters and #3185-3400 meters.

(2) Dr. Yamamura, Tokyo Imperial University.

Among the records available for examination and verification there were a few cases where second degree burns were received by patients at distances greater than 2500 meters. In general, however, it is proper to say that the majority of the second degree burns occurred within a radius of 2500 meters, which is 1.75 miles. Very precise measurement of the distance of burned patients from the bomb was possible in the case of sailors on ships anchored in the harbor. 4 men who were sunbathing on the Chidori-Maru anchored 3100 meters from the point below the bomb, received "moderately severe" burns, some of which were second degree. They recovered in 2-3 weeks. Thirteen other sailors at work about the ship received "minor" burns. Three men aboard the Tsuruoka-Maru, anchored at 4000 meters, received slight burns, presumably 1st degree. Measurements of similar accuracy were possible in the case of several small boys who were swimming at the Fishers' Wharf, exactly 2800 meters from the center. Some of these received severe second degree flash burns, portions of which were of the third degree.

An interesting footnote to this section on the relation of the amount of heat delivered to the patients is the following statement from Ashe & Roberts (1) article:

"It may be of interest that above 300°C up to the limit of the present study (500°C) Prince Albert cigarette paper makes an excellent substitute for skin in trial procedures. First visible charring of the paper occurs apparently at time-temperature relationships which cause first degree burns." (See table 6).

In addition to human burns, scorching of many materials, including clothing, granite, tile, etc. was observed. The time-temperature relationship

(1) Loc. Cit.

for these materials is not known so that estimates of the temperature required to cause bubbling of roof tiles for example, are comparatively meaningless. (2). The bubbling of tile was observed in Nagasaki at distances as far as 1000-1500 meters from the center of the explosion. Unpainted wooden surfaces (telephone poles) (figures 12 and 13) were scorched at distances as great as 3100 meters from the bomb. These "flash burns" of material objects (figure 12) were of considerable value in estimating the height and the precise location of the exploding bomb. Studies of them add little, however, to an appreciation of the heat generated, as judged by the effect on the people. An examination of some of the shadow effects permitted an estimate of the maximum duration of the heat-flux. In Figure 2 are shown clearly delineated shadows of tall grass on a scorched wooden fence meters from the bomb. From the sharpness of the outline of the shadows it is proper to assume that the grass did not move during the "flash". We know, however, that the blast wave which travelled with the speed of sound, 340 meters per second, could not have reached the fence while the heat intensity was great enough to scorch it. From a number of such observations at various distances, it is quite definite that the heat did not last for longer than one second. The

(2). The differential in temperature required to scorch white and colored cotton cloth has been studied at the Naval Medical Research Institute. The critical temperature for colored cloth is 200°C and for white cloth it is 230°C. The duration of exposure of cotton cloth to this temperature to produce scorching is not stated.-Personal communication, Capt. Shields Warren, (MC) U.S.N.R.

Experiments with roof tile from Nagasaki showed that "similar" bubbling was produced by 1800°C for 4 seconds.

sharpness of the edges of the flash burns on people also bears out this contention. In a like manner, the infrequency of corneal burns (1) indicated that the heat-flux was of sufficiently long duration, that the rapid blink reflex protected the eyes before the full intensity developed. The blink reflex requires, on the average 0.01 second from strong stimulus to complete closure of the lids. From such consideration it is possible to deduce that the duration of the flash was longer than 0.01 seconds, and shorter than 2.0 seconds.

On the basis of the material which has been presented, it is apparent that radiant heat emitted by the exploding bomb was the cause of the flash burns. It is desirable, however, to consider two other possible causes of some of the burns.

a) Beta rays

b) Gamma rays or X-rays

The likelihood that beta rays may have caused some of the burns was not considered during the time the Joint Commission was in Japan. The physicists were quite certain that no beta rays were received by patients outdoors, unshielded, who survived. None of the members of the Joint Commission had any knowledge of the sort of burn that would result from suitable exposure to them. Accordingly, the report of Robbins, et al. (2) on accidental burns from scattered cathode rays was read with much interest. There does not appear to be any reason to believe that the skin lesions in any of the Japanese exhibited the distinctive features so clearly illustrated and described in this article.

The characteristic features of gamma ray burns and X-ray burns are:

(1) One Japanese report said that 20% of the burned patients had "blistered eyeballs". This observation is not supported by any other clinical reports.

(2) Robbins, L.L., et al. "Superficial Burns" of skin and eyes from scattered Cathode Rays." Radiology 46: 9, 1946

1) The appearance of erythema 1 to 3 weeks after exposure.

2) The small amount of edema in comparison with thermal burns.

3) The persistence of "deep" pain during the acute stage.

4) The slow desquamation, and the protracted period of healing with atrophy and telangiectasia.

5) "Dirty" pigmentation of the irradiated areas.

6) The inverse relation to the intensity of the radiation, as measured in air, so that roentgen burns are more severe after a certain amount (in r) of low voltage radiation, than after the same amount (measured in air) of high voltage radiation.

One feature of roentgen-type burns observed in Japanese patients was the dirty pigmentation. Because of the varied conditions of healing of the thermal burns (see below, tables 9 and 10) the only pigmentation which could be ascribed to ionizing radiation was that seen in the skin which had not received a "flash burn". The incidence of pigmentation of the skin was not very great. The data obtained in the questionnaire study are given in the Statistical Section. This particular finding was not recorded with any degree of accuracy because of its vagueness. It is true that patients with radiation sickness were observed whose skin was pigmented in the manner observed after "heavy" roentgen therapy. It is also true that some subjects without evident radiation sickness insisted that their skin was darker than it was before the bombing. This type of data is obviously very unsatisfactory, and it is necessary to state that the incidence of "roentgen pigmentation" is not known. It can be said, however, with considerable certainty,

that there was no definite evidence that the cutaneous burns were caused only by the gamma radiation and there is very little reason to believe that the gamma rays altered the appearance of the thermal burns. It was the impression of most of the observers that the gamma radiation had not affected the course of healing of these burns to an extent that could be proved,

Clinical Features:

The Japanese clinical records contained very little information on the symptoms which occurred in association with the burns. This is not surprising for two reasons: first, in the early stages the doctors were extremely busy and assumed that the burns were no different than other flash burns, and second, by the time they began to wonder about the nature of the burns, symptoms of radiation injury were becoming manifest and overshadowed all other clinical considerations. For this reason, there is only one small series of patients who were interrogated specifically about their burns. (1). The answeres which are shown in Table 8. were in reply to questions about the period immediately after the explosion. In all cases, within a very short time, the burns became very painful, and some of the eye witness accounts (2) describe the burned patients plunging into the river to get relief. Although the Japanese do not use the term "shock" in the sense that it is used by Western physicians, the description of the condition of the burned patients on arrival at Omura Naval Hospital during the night of 9-10 August, clearly indicates that in many, shock was developing or was already present.

(1) Nakashima report, Appendix 4 N (19).

(2) Appendix 3 N.

". . .in spite of their severe injuries, the majority of the patients were quiet as though in a collapsed state." (1)

TABLE 8

THERMAL INJURIES

IMMEDIATE SYMPTOMS	NUMBER
Felt heat at the time of the blast.	11
Felt pain in burned areas at once	14
Felt neither heat, nor pain.	18
Total	39
Hair singed or burned	4

The appearance of the flash burns at various stages can be presented most satisfactorily in the pictures that accompany this section. The illustrations have been chosen because they are typical of the lesions that were observed.

Figure 14 (NP 153) shows the body of a man who was dead on admission to hospital approximately 12 hours after the bombing. His distance from the bomb was not recorded, but Japanese records describe this type of 2nd and 3rd degree burn in people who were in the open within 1000 meters of the center. The dark, even black, charred appearance of the burns is mentioned in many of the eye-witness accounts, and may be seen in pictures of groups of cadavers close to the center. In some cases the burns were so severe that the patient could not be identified, and in extreme cases, it was said that the sex could not be determined. (1)

Figure 15 (NP 105) is a woman who was lying prone in the open, at a

(1) Shiotsuki report, Appendix 4 N (4)

distance reputed to be 500 meters from the center. She was wearing black clothing and received 2nd and 3rd degree burns of the back, buttocks and legs, and 3rd degree burns of the back of the feet. These burns became badly infected and contractures developed. Bilateral Achilles tenotomy was done to correct them. She also developed typical symptoms of radiation sickness, except for epilation. She died 15 October 1945. Further notes on her case may be found in the Pathology section.

Figure 16 (NP 102) is a man who was sitting inside a house at 800 meters, wearing a white, short-sleeved shirt, trousers and cap. His position in relation to a window was such that he received 2nd degree burns of the left side of his face and neck and slight burns of the left arm and both hands. The photograph shows a common complication of flash burns of the ears. A perichondritis has developed and with recovery the patient has a "cauliflower ear". In this man the healed skin is depigmented, and there is a distinct zone of increased pigmentation between the burned and the intact skin.

Figures 17 and 18 (NP 123 a, b) show a man standing in the precise position in front of his home where he was when the bomb exploded. The measured distance to the center (by U. S. engineers) is 900 meters; and as cen be seen in Figure 18 there was nothing to intercept the heat rays. He was wearing a heavy khaki military jacket, trousers, gaiters and a cap and was looking toward the sky away from the bomb. He received 1st and 2nd degree burns of the ears, the back, the elbows and the left hand. At the time of the photograph, in November, the burns were healed. There is a prominent zone of hyperpigmentation between the burned and the healthy skin. The cotton clothing that he wore was scorched and "destroyed" over the burned areas.

He was blown about 4 meters by the blast, but was not injured. Epilation, purpura, and gingivitis occurred, but he recovered from the radiation injury.

Figure 19 (NP 160) is a man who was standing in the open, 1000 meters from the center, wearing a white shirt, pants and leggings. He received 2nd and 3rd degree burns of his face, neck, left arm, right elbow and back. The condition of the healing 2nd degree burn is shown, with general depigmentation and a narrow band of hyperpigmentation adjacent to the healthy skin. Keloid formation is apparent on the right elbow, and the bandage conceals exuberant granulation tissue in the 3rd degree burn. Epilation occurred, but there were no other symptoms of radiation injury.

Figures 20 and 21 show a woman who was sitting near a window inside a wooden building at 1200 meters. She wore a light shirt, long khaki pants but no shoes or sox. She received mild 2nd degree flash burns of the face and neck and severe 2nd degree burns of the legs and feet. She also received many small lacerations from fragments of glass (the window panes). Epilation of the scalp and eyebrows occurred. The skin of her body, particularly of her chest, gradually developed a dirty pigmentation in the unburned areas, under her shirt. The contrast of this pigmented skin with the comparatively depigmented burned area is shown in Figure 21. Here again is seen the narrow band of excessive pigmentation at the margin of the burn. There was some question among members of her family whether the healed skin of her face and neck was paler than before the bombing, and the consensus was that the color was approximately normal. Keloid formation may be seen in the healing burns of the left knee and the dorsum of the left foot. (figure 20).

Figure 22 is a woman who was sitting in the open "behind a tree", at 1300 meters. She wore dark brown and black clothing and all the burns,

except those of the face, neck and hands occurred under this clothing. The head bandage covers a perichondritis of the right ear. The 2nd degree burns of the rest of the skin healed, and there is a contraction at the right elbow and hand. The healed skin of the neck and the left shoulder is depigmented; while that of the left forearm shows a not uncommon pattern: the healed skin is of approximately normal color, except for a zone of depigmentation adjacent to the unburned skin. Because of a history of vomiting on the day of the bombing and a record of leukopenia, a diagnosis of radiation injury was made.

Figure 23 is a man who was standing in the open, at 1400 meters. He wore green trousers, but no cap, shirt or shoes. He did not know what protected his face and head from the flash. He received 2nd degree flash burns of the right side of his chest and left arm and some 3rd degree burns of his right arm. He stated that all the skin of his body had become pigmented, and it was seen to be of an even dirty brown color. The healed flash burns showed the same type of pigmentation, but as can be seen, the distribution was irregular.

Figure 24 is a girl who was also standing in the open at 1400 meters. She wore a short-sleeved green shirt, green trousers, and a cap. This photograph was made during August by the Japanese, and it shows the early stages of healing of a severe second degree burn of the face, neck, shoulder, arm, and back on the right side, and both ankles and feet. The lesion over the sacrum is either a decubitus ulcer or a 2nd degree burn. The photograph gives the impression that the unburned skin is deeply pigmented, but there is no mention of this in the record of the Joint Commission. This patient vomited on the day of the bombing, and the only white blood cell count recorded was 4800 on 20 September. There was no other evidence of radiation injury. The burns were

healing slowly in October, and the patient was definitely recovering at that time.

Figure 25 is a man who was walking directly toward the direction of the blast, looking at the B 29's. He was 1600 meters from the center, and has provided a useful eye-witness account of his experiences. (1) He was fully clothed, and wore an air-raid warden's steel helmet. The burns on his chest and arms occurred through dark colored clothing. The condition of the healed 2nd degree burns shown in the figure is very interesting. All of them are deeply pigmented in contrast to the intact skin. There was some hyperemia of the lesions. The skin of the face had a bronzed color with marked contrasts between the burned and the small shadowed areas under the supraorbital ridges, nose, chin, etc. This type of visage has been called the "Mask of Hiroshima" since it was seen much more frequently there than in Nagasaki. The pigmentation of the skin of the face and the neck of this patient has a striking resemblance to pellagra both in color and in distribution. In some instances the likeness was accentuated by the occurrance of similarly pigmented healed burns of the hands. This patient did not have epilation (the steel helmet?) but had a mild transitory purpura, from which he made a good recovery.

Figure 26 (NP 120) is a man who was standing in the open at 2000 meters. His back was to the bomb, and his head was turned to the left. (This may be inferred from the jagged line of demarcation due to skin wrinkles between burned and intact skin of the neck.) He wore a shirt and trousers and received the burns shown underneath the clothing. He states that his "shirt burst into flames" at the instant of the flash, and this may account for

(1). See appendix 3 N.

the severity of these burns, most of which were 3rd degree. The burns on the buttocks were healed, with depigmentation, but in the case of the back, infection and the exuberant granulations have obviously retarded healing. As a consequence of this severe injury he was markedly emaciated when last seen in November, 1945. He stated that epilation occurred in August; but there was no gross evidence of it in October. The blast wave knocked him down, but he did not lose consciousness.

Figure 27 is a man who was lying prone in the open at 2100 meters, on a hillside. He was wearing summer clothes, which in the case of a farmer would be light colored. He received the 2nd degree burns which are shown, mainly under his clothing. There is no explanation for the shadow effect to be seen on the left loin and the left arm. In addition to the burns, he received radiation injury followed by epilation and severe ulcero-necrotic pharyngitis, from which he recovered. These 2nd degree burns have become more deeply pigmented after healing than is the surrounding skin, and there is no zone of hyperpigmentation as in the case of the depigmented burns.

Figure 28 (NP 121) shows a boy who was outdoors "behind" some trees at 2200 meters. He wore a white shirt and white shorts. It is apparent from the irregular margin of the burns of the neck that he was looking upward and to the right. In addition to the burns shown in the photograph, he received 2nd degree burns of legs, feet, and buttocks. All the burns were healed in November when the picture was made, and those under the white clothing were obviously less severe. It can be seen that in this case, the healing skin is less pigmented than the intact skin and that there is a narrow line of hyperpigmentation at the junction of the two. He described a slight amount of epilation in September but there was no indication of it or of other

signs of radiation injury when he was examined by the members of the Joint Commission in October.

Figure 29 (NP 111) is a man who was standing in the open at 2400 meters. He was wearing a sleeveless white shirt and white shorts and was burned only on the exposed portions of the skin. The burns of the arm appear to be of 2nd degree, and have healed with some contracture of the skin. The burns of the face appear less severe, but a close inspection of the print will disclose the irregular pattern of unburned "shadows" giving the mask-like appearance. The color of the healed burns was darker than that of the intact skin; part of this was due to pigmentation, and part to a persistent erythema due, possibly, to dilated capillaries. This man said that he was blinded by the flash and could not see for 2 days afterwards. On examination, the eyes were normal in October.

Figure 30 (NP 114a) shows the left forearm of a man who was standing outdoors at 2400 meters. He was wearing a short-sleeved shirt and received burns only on uncovered skin. The photograph shows a considerable degree of keloid formation in the center of the burn. Changes in pigmentation are visible between the keloid and the healthy skin.

Figure 31 (NP 100) shows healing 2nd and 3rd degree flame burns of the legs of a man who was inside a concrete factory building 1300 meters from the center. The building was damaged by the blast, and all the wooden interior trimmings burst into flame. The patient was wearing gaiters and heavy shoes, but was burned as he escaped from the flames. Exuberant, infected granulations and some alterations in pigmentation at the healing margins can be seen. There is some keloid formation in the healing lesions on the right leg.

These illustrations which have been presented in the order of the distance of the subject from the bomb. show quite well some of the main features of the flash burns observed in Nagasaki.

1. The skin that was burned was the skin which could receive direct light rays from the bomb.

2. Clothing was protective to a variable degree, depending on some undetermined relationship between the heat delivered and the weight, composition, and color of the clothing.

3. Parts, like elbows or shoulders, over which clothing is often tightly stretched, were frequently burned when other clothed areas escaped.

4. The appearance of the healing burns with the exception of the pigmentary changes does not appear different from the healing of other thermal burns of equal severity and extent.

Although there was considerable discussion among the Japanese and the American doctors about the character of the healing burns, very few reports are available where the end result is described. The interest in the nature of the healed burns revolves around the question of degree of interference with healing, if any, which may be attributable to the gamma rays. It is impossible to deny that all patients with flash burns received some dosage of ionizing radiation inversely proportional to their distance from the bomb. The desirability of special studies of this problem was not appreciated until the Report was being prepared and then it was necessary to rely entirely on the photographs. Of the photographs available for such a study, 14 have been presented in this section, Figures 15-30, inclusive. After tabulating the salient features of the healing burns: pigmentation, depigmentation, the zone of hyperpigmentation, and keloid formation, it

was found the patients formed two fairly distinct groups. The results are shown in Table 9. It is regrettable that there are so few reliable observations, but the trend appears definite:

TABLE 9

CONDITION OF HEALED BURNS (1)

DISTANCE FROM BOMB. METERS		DEPIGMENTATION OF HEALED SKIN	PIGMENTATION OF HEALED SKIN	ZONE OF HYPERPIGMENTATION	KELOID
Less than 1400	Present	5	0	4	2
	Absent	1	6	6	4
Beyond 1400	Present	3	7	2	2
	Absent	5	1	6	8

a) At distances closer than 1400 meters the healed burn tends to be depigmented with respect to the intact skin; and there tends to be a narrow zone of hyperpigmentation separating the two.

b) At distances farther than 1400 meters, the healed burn tends to be pigmented with respect to the intact skin and the narrow zone of hyperpigmentation is seen less often.

c) Keloid formation was more frequent in burns received at distances less than 1400 meters.

One Japanese report (1) presented data on the condition of the healed skin of patients who received flash burns in the Ohashi Works-1100-1500 meters; and in the Morimachi Works-1300-1500 meters. (See table 10). Apparently only the major single condition in each case has been tabulated. There is a reasonable degree of similarity between the data in Tables 9 and 10. An interpretation of the significance of these apparent differences in the state of the pigment in healed flash burns is difficult when the number of cases is so small.

(1) Nakashima report, Appendix 4 N (10).

It may be pointed out, however, that 1000-1100 meters has been estimated as the distance from the point on the ground beneath the bomb at which the LD-50 (amount which killed 50% of the subjects receiving the dose) of gamma rays was delivered.

TABLE 10

CONDITION OF HEALED BURNS

Pigmentation of healed skin	21
Depigmentation of healed skin	13
Keloid formation	5
Atrophy of skin	2
Dilatation of capillaries	2
Total Cases	44

Because of the almost universal infection of 2nd and 3rd degrees, and because of the uncertain effect of the gamma radiation it is not possible to offer a fair generalisation on the rate or quality of the healing process. The data collected by the Joint Commission does not contain information suitable for analysis. The most that can be said is that on 27 November, 90 days after the bombing, when the American members of the Joint Commission left Nagasaki, there were still patients in the hospital with 2nd and 3rd degree burns that were far from healed.

S U M M A R Y

1. The most frequent type of thermal injury was a flash burn, caused by radiant heat (consisting of infra-red rays, visible and ultra-violet light) emitted during the explosion.

2. The overall incidence of burns is not known, and estimates vary from 35% to 60%. Among persons who were unprotected by any material objects between them and the air burst, the incidence was probably 100% for those within a radius of 3000 meters, (2 miles).

3. Second degree flash burns were inflicted on exposed skin to a distance of at least 2500 meters (1.75 miles). First degree flash burns occurred at a distance as great as 4000 meters, (2.5 miles).

4. Clothing was protective to a variable extent depending on the quality, color and the intensity of the heat; but burns occurred under clothing at least as far as 2500 meters from the center.

5. There is no record of any person who survived the effects of burns received (in the open) at distances less than 500 meters from the center.

6. In the vicinity of the center, and within a radius of 400-500 meters, most people in exposed positions were instantly killed, burned to death.

7. The healing flash burns displayed certain variations in the pigmentation, the significance of which is not apparent from the available data.

8. There is no proof that the healing of the burns was, or was not, modified by any effect of ionizing radiation on the skin.

(4) Radiation injury. General:

The third major casualty-producing agent, ionizing radiations, is the one which differentiates the atomic bomb from all other weapons. The gamma rays and neutrons which were emitted not only contributed materially to the total mortality and morbidity, but they also performed a biological experiment of unprecedented scope. Total body roentgen irradiation has been employed therapeutically since about 1932, but there are no reports in the medical literature of the amount of X-rays, gamma rays, or neutrons which is lethal for humans. Single doses of total body radiations are usually given so cautiously that the amount seldom approaches the lethal dose. In the case of laboratory animals, many studies have been made with single doses of roentgen rays of all intensities up to 1200 KV. The LD 50 (the amount which will cause the death of 50% of the animal exposed) for X-rays is known for a variety of laboratory animals, and is of the order of 300-700 r. The biological effects of neutrons, fast and slow, are currently under investigation. The LD-50 for some animals is known, and the biologic effectiveness compared to X-rays has been reported. There have been no experimental studies reported where the biological effects of mixtures of gamma rays and neutrons were studied.

In Japan, during the explosion of the atomic bomb, total body irradiation with a mixture of gamma rays, X-rays, and fast and slow neutrons was administered to thousands of people. Because the people were exposed at varying distances from the bomb, and because some were shielded by various thicknesses of different material, it is proper to consider that the quantity of radiation received varied from many times the lethal dose to infinitely small amounts.

This section of the report has been prepared from two points of view: (1) As a casualty study of the effectiveness of ionizing radiation as a war weapon; (2) As a clinical study of the natural history of the disease syndrome caused by large amounts of ionizing radiation.

The most appropriate nomenclature for the syndrome has been considered. The commonest designation used by the Japanese investigators was the "atomic bomb disease". The members of the Joint Commission felt that the terms "radiation sickness", "irradiation sickness", and "roentgen sickness" were used rather generally to connote the symptoms developing during roentgen therapy and radium therapy. Because of the manner in which the disease occurred, the use of the term "injury" in the name seemed appropriate. The question then was whether to refer to "gamma ray injury", or simply to "radiation injury". Since gamma rays were not the only ionizing radiation responsible for the disease, it was felt that the "syndrome of radiation injury", or simply "radiation injury" was the preferred name. "Radiation disease" has been used alternatively. There has been no inclination on our part to emmulate, or perpetuate any of the names with Greek roots that some of the Japanese coined: panmyelophthisis, panhistopathia, etc., for example.

Incidence: In the conventional military sense, a "casualty" may be defined as one who is killed or is forced to withdraw from an action because of wounds, or disabilities pecular to the circumstances of combat. In the sense of immediate disability, the term "casualty" is not always applicable to a person with radiation injury. Although some people who received lethal doses of ionizing radiation had symptoms on the day of exposure, it does not appear that many were disabled at once. Because of the latent period between exposure and the onset of disabling symptoms, it is necessary to take a

broader view; and in connection with radiation injury, a "casualty" must be taken to mean any person who later died or became sick enough to require medical attention, or sick enough to discontinue his habitual occupations. In ordinary warfare, it is usually possible to determine the number of casualties that occur each day, or in each phase of battle. In "atomic warfare" it may be weeks before the total number of casualties can be counted correctly. In Japan it was impossible for the Joint Commission (or the Japanese authorities) to determine any of the following facts:

(1) The total number of persons who received radiation injury, alone.

(2) The total number of persons who received radiation injury in addition to other injuries.

(3) The percentage of persons with radiation injury (either 1 or 2) who died as a direct consequence of it.

In the case of radiation injury, not all the blame for the lack of information can be ascribed to deficient records. Other factors were: (1) The failure of the Japanese to recognize the existence of radiation injury in patients with serious wounds and severe burns; (2) the lack of definite criteria on which to base a diagnosis. The first factor applied to the earliest cases, within perhaps one week of the bombing. The second factor applied to later stages when many frank clinical examples of radiation injury occurred. The obvious cases were recognized, but there was a large group of sick people, some of whom had radiation injury which was not diagnosed, and others who were said to have radiation injury when some other disease was responsible. As a consequence, there is no satisfactory estimate of the number of persons injured by the ionizing radiation. The Joint Commission's questionnaire were studied carefully, and criteria for the

clinical diagnosis of radiation injury were formulated. The reader is referred to the statistical section for a detailed presentation of this problem which was the primary concern of the statistician. With the criteria that were decided upon, it was found that the incidence of radiation injury among the entire group of 3800 patients surveyed was about 35%. This means very little actually because of the dimishing amounts of ionizing radiation to which people were exposed at increasing distances from the center. The incidence among the most exposed group for example, (Exposure Group A) was 53% - 65% within 1000 meters of the center. The incidence decreased steadily to 2000 meters (See figure 32) and only a few authentic instances of radiation injury were encountered farther than that. The entire subject of the relation of the incidence of radiation injury to distance, shielding factors, etc., is presented in the statistical study, Section 9.

The data on "the case-fatality rate is even less satisfactory. The Japanese stated that of the patients in whom the syndrome of radiation injury occurred in a "very severe form" (see below), with symptoms beginning shortly after exposure, 100% died. In the "severe form", in which there was a latent period of one to two weeks before symptoms appeared, the mortality rate was said to be 50%. Individual hospitals, where small numbers of such patients were studied, reported death rates during the 3rd to 6th week after the bombing, that varied from 100% (216 Field Hospital) to 20% (Sawada Clinic). In the well-appointed clinics, about one-third of the patients died, while in the aid stations the rate was much higher. Except for a few verifiable data, these estimates represent the personal opinions of Japanese physicians who were in attendance. There was a general agreement on the 50% death rate for the "severe" cases as an overall estimate. During the period, 1 October to 27 November, while the Joint Commission was in Nagasaki, approximately 1000

patients with radiation injury were studied. Of this number, about 400 were under continuous observation in hospitals, and of these 21, or 5% died.

The estimates referred to are the best available, but are all too low, In one small group in the Fuchi School, for example, 90% of persons 1000-1100 meters from the center had evidence of radiation injury. The lower values found in the statistical study probably represent the effect of protection and selection on the incidence rate.

Etiologic Factors.

The ionizing radiation responsible for radiation injury consisted of gamma rays and varying amounts of fast and slow neutrons. The source, the quantity and the energies of these radiations is properly the concern of physicists, and has been described in Section 2. Most of our knowledge of the physiologic effects of radiation is empirical, based on observations of the effect of large doses on laboratory animals; and the effect of small doses administered therapeutically to patients. The theories of the possible modes of biological action of radiation are not very helpful in interpreting clinical material. A recent monograph, Lea (1) makes the following observations: "We shall take it for granted that the biological effects of ionizing radiation are due in some way to the chemical changes induced by the radiations. We are immediately faced with the problem of explaining why marked biologic effects are produced by doses of radiation which produce only a small degree of chemical changes. There are several ways, however, in which a small overall percentage chemical change may be imagined to be effective . . . .

(1) Lea, D.E., loc. cit. p. 64

These ways may be presented briefly as follows:

(1) Activated Water Reactions: In solution the radiation produces H/ and OH- ions from the water. The capacity of these ions to affect oxidation-reducing systems, and enzymes has been demonstrated, and "dilute solutions of enzymes may be largely inactivated by doses of a few thousand roentgens." (1)

(2) Direct Action on Large Molecules: In a general way, a chemical change (i.e. by ionization) in a certain proportion of the molecules of a substance by direct action is inversely proportional to the molecular weight. Thus, of the molecules exposed to ionizing radiation, the largest ones are the most likely to be damaged, or inactivated by ionization.

(3) Localization of Ionization: This refers to the occurrence of ionization within or near structures which are sufficiently vital for changes in them to affect the cell as a whole. This effect has been studied particularly in respect to chromosomes and genes. The passage through these structures of an ionizing particle of sufficient energy will produce changes which may be microscopically visible or genetically evident.

(4) Cell Poisons: "The products of decomposition of proteins and other cell constitutents by radiation have not been much investigated, but it is quite possible that they may be injurious in quite low concentrations. It is possible that there are some biological effects due to this cause. There is not much one can say, however, about their mechanism . . . . ".(1)

In general, it is accepted that the biological actions of radiation are due to the ionization that occurs in their passage through tissue. It is also recognized that the degree of damage depends on the amount of ionization that occurs. For this reason, regardless of the nature of the radiation to which tissue is exposed, equal amounts of ionization are believed to

(1) Lea, loc. cit. page 65.

cause equal effects. A precise interpretation of the effect of the radiation emitted by the atomic bomb would be possible only if the ionization in tissue of the mixture of gamma rays and neutrons was known. Since neither the dose measured in air nor the composition of the radiation is known, estimates of the depth dose appear to be unobtainable. Because of the gaps in our knowledge of the characteristics of the radiation delivered to the Japanese, it is only possible to describe the symptomatology and the lesions observed at autopsy. It is not possible to attribute these findings to so many roentgens (measure in air) on the basis of experience with radiotherapy or animal studies. Naturally, the effects studied will be less at greater distances from the bomb; but whether a given effect will follow the inverse square law is not certain because of the mixed character of the radiation and the different amount of ionization produced in tissue by neutrons and by gamma rays of various intensities.

The LD-50 of the ionizing radiation of the plutonium bomb was delivered to people in a light wooden building at a distance of 1000-1100 meters from the point on the ground beneath the explosion. The evidence for this observation is fairly reliable, and is presented in Section 11 N.

The relative amount of ionizing radiation which will cause detectable injury to a cell is an inherent characteristic of the cell, and is referred to as its radiosensitivity. Variations in the radiosensitivity of different tissues is well known, and is related, roughly speaking, to the rate of growth and rapidity of reproduction of the constituent cells. In the human body, the cells of the lympho-hematopoietic system, the gonads, the skin and its appendages, and the intestinal mucosa are the most radiosensitive, in about the order named. In the clinical discussion that follows attention

will be directed primarily to these tissues.

It is well recognized at the present time that all the effects of ionizing radiation are harmful. The degree of injury may vary from one that can only be inferred by its late effects to immediate death of the cell. The degree of injury in any given instance depends on the relationship between the radiosensitivity of the cell and the amount of ionization produced in it. The physiological status of a tissue at any time after irradiation represents an equilibrium between the effects of the injury and the amount of recovery or regeneration that has occurred.

The various complex interrelationships that have been mentioned above all contribute to the difficulties of presenting and interpreting the clinical syndrome due to radiation injury.

Clinical Considerations:

The greatest difficulty to be overcome in the presentation of the clinical findings is not the matter of dosage of radiation, but the interpretation of the role of complications in the genesis of symptoms and in the causation of death. The elements of the problem are as follows:

1. Ionizing radiations caused certain clearly recognizable changes in some tissues.

2. It may be inferred that lesser degrees of injury, which cannot be recognized at the present time, occurred in the less radiosensitive tissues.

3. Because of (1) and (2) Pathogenic bacteria, whose proliferation and invasion of tissue is normally restricted, were able to flourish and produce serious local and general infections.

4. The infections produced their own symptomatology and frequently were the cause of death. Accordingly, the problem is to separate wherever

possible, the syndrome into its two components: a primary portion due to ionizing radiation, and a secondary portion due to complicating infection. This is important because to a large extent the character of the illness, and the manner of death was determined by the nature of the complicating infection. The particular strains of bacteria that caused the infections, and in many instances the lesions which provided a portal of entry for the infection, were determined accidentally, and should not be considered as primary pathologic agents in the same sense as the ionizing radiations. To provide a basis for the distinction between the primary and secondary phenomena, a list of the tissues in which histological changes occur which can be attributed to ionizing radiation, is shown in Table 11. It is plausible to believe that the function of many other cells of the body was disturbed to a varying extent, but there was no histological, and little physiological evidence for this belief.

TABLE 11

Tissues that were destroyed or damaged to a sufficient extent that typical changes were found on microscopic examination.

1. Lymphopoietic system.
   a. Lymphocytes of circulating blood.
   b. Lymphopoietic portions of lymphatic tissues.
2. Hematopoietic System.
   a. Leukocytes of circulating blood.
   b. Myelopoietic, erythropoietic and thrombopoietic portions of bone marrow.
3. Gastro-intestinal System.
   a. Mucosa of intestines.
   b. Mucosa of esophagus and oropharynx.

4. <u>Cutaneous System.</u>

   a. Hair follicles

   b. Sweat glands and epidermis

5. Reproductive System.

   a. Germinal epithelium of testis.

   b. Primary follicles of ovary.

<u>Classification</u>: It is appropriate to assume that among the thousands affected by ionizing radiation every degree of injury from the most severe to the mildest occurred. It might be anticipated on this basis, that distinct clinical syndromes would not be recognizable, but that there would only be gradations of severity. In actual practice it was rather easy to subdivide the cases into 4 groups on the basis of symptomatology and outcome. This classification, which is shown in Table 12, is the same as the ones presented in the Blood Section (6) and the Pathology Section (8). The symptoms which form the criteria were used because of their obvious prevalence, their relation to the pathological lesions, and because the statistical study demonstrated the greatest correlation with radiation injury. The approximate mortality rate and the time-period during which death occurred provided a substantial basis for grading the cases. It will be seen in the Pathology Section (8) that this division of the fatal cases was very satisfactory. The relationship of distance from center to the severity of radiation injury is only an approximation, but it appears to be valid for the majority of the cases. It should not be given too much weight, however, for shielding by heavy construction and individual radiosensitivity resulted in many exceptions. The effect of shielding on the syndrome of radiation injury is considered in detail in the Statistical Section (9).

TABLE 12

CLASSIFICATION OF CLINICAL TYPES OF

THE SYNDROME OF RADIATION INJURY

	VERY SEVERE	SEVERE	MODERATELY SEVERE	MILD
Approximate Mortality	100%	50%	Less than 10%	Nil
Time of Death, Weeks	1st & 2nd	3rd - 6th	6th -15th	-
Nausea & Vomiting day of bomb	+ + +	+ + +	+ +	±
Leukopenia	+ + +	+ + +	+ +	+
Epilation	±	+ + +	+ +	±
Purpura	+	+ + +	+ +	+
Oropharyngeal Lesions	+	+ + +	+	-
Approximate Distance from Bomb, meters.	Less than 1000	1000	1000-1500	More than 1500

In the remainder of this section, the 4 clinical types of the syndrome of radiation will be considered separately. Because of the diversity of the material, a certain amount of simplification is desirable. Accordingly in the description of the types of cases, the discussion will be restricted to the main symptoms of epilation (and skin changes), oropharyngeal lesions, purpura, fever, diarrhea, and nausea and vomiting soon after irradiation. An analysis of the significance of these symptoms may be found in the Statistical Section. In addition to these observations, it is necessary to present summary of a

large amount of clinical research conducted mainly by the Japanese. These studies were performed on convalescent survivors, as a rule; and frequently the records do not permit a clear distinction of the type of case studied. The presumption may be made, however, that the majority of subjects were examples of the severe and the moderately severe and the mild types of radiation injury. This material will follow a systematic review of symptomatology.

Very Severe Cases: There are not very many reports available from Nagasaki concerning this type of case. During the first two weeks after the bombing there was a shortage of medical personnel, and the few hospitals that were functioning were over-crowded with burned and severely wounded patients. At the Omura Naval Hospital, the majority of the patients with very severe radiation injury were burned and the clinical records contain little data of value except the blood counts and the temperature record. Brief summaries of the records of 3 typical examples are presented below. Many more such cases were observed at the 216 Field Hospital (temporary), but no records of specific examples were obtained. The general remarks of the Commanding Officer of this installation have been used in the description that follows:

Onset: Nausea and Vomiting occurred to all patients of this type shortly after the bomb exploded. There is no detailed account of the circumstances of this symptom for individual patients, but in the majority it appears to have been persistent, and to have continued for several days, and in some cases for the entire course of the illness.

Fever was present, apparently from shortly after the onset, in all the patients with the very severe form. It increased in amount each day, and in the majority was a continuous fever of 40°-41° C at the time of death.

Course: The course of the very severe cases was continuous in the sense

that from the appearance of nausea and vomiting until death there were no remissions of the symptoms or signs of the disease. Rather there was a steady progression in the severity of each symptom from its inception until death. This factor, the tempo of the development of the syndrome, seems to be one of the most important means of estimating the severity of radiation injury early in the course of the disease.

Diarrhea: was a prominent feature of the course of nearly all the patients. Its onset varied from the day of bombing to the day of death. The stools were described as watery, green-colored, often containing mucus, and less frequently, blood. The number varied from several to 15 per day, and the character of the stools and the rectal tenesmus that occurred resembled the findings in bacillary dysentery. Associated with the diarrhea, there was abdominal cramping and tenderness on palpation. In the report of the 216 Field Hospital (temporary) it is stated that 17% of the early admissions developed this type of diarrhea, which was rapidly recognized as a specific entity. All the patients with this sort of diarrhea died.

Skin Lesions: Several of the reports mention the occurrence of bullae, or large vesicles in skin which had not been affected by the heat. The available descriptions of these lesions, which occurred apparently only during the first few weeks, are quoted verbatim:

"There were 4 cases of death after the patients developed blisters the size of a pigeon's egg scattered on the skin without any apparent cause. Death came in 2 days." (1)

"During the prodromal period (i.e. 1st 1-2 weeks) bullae varying in size from a thumbprint to a hen's egg appeared in various places. These may

(1) Appendix 4 N (5).

be compared to roentgen-ray erythema (sic), or may be the result of radio-active material adherent to the skin."(1)

No photographs or other material is available to illustrate this process in the very severe cases, but several examples are shown in the section where severe cases are discussed, (See below).

Among the very severe cases which were studied at the Omura Naval Hospital, the occurrence of herpetiform lesions about the mouth was a common finding. An example of these lesions is seen in Figure 33. None of the other contemporary reports mention them.

Purpura occurred as early as the 3rd day after the bombing in some patients of the very severe type. In others, cutaneous purpura did not occur before death, but hemorrhagic lesions of the viecera were seen at autopsy. The frequency of this symptom increased during the 2nd week of the illness. Epilation. of the scalp commenced as early as 14 August, the 6th day after the bombing. During the 2nd week many of the moribund patients developed this symptom. The hair of these patients came out very easily and it is stated that simply passing a wet hand through the hairs would remove many of them. The contemporary reports are somewhat contradictory about the amount of epilation of other than scalp hair.

Terminally, many of the patients displayed neurologic symptoms of various sorts. Subpial and subarachnoid hemorrhage was found at autopsy in some of them, but the records are so inadequate that the relation of the symptoms to trauma cannot be determined.

The blood picture in cases of the very severe type is described in the Blood Section (6), and consisted of marked leukopenia, anemia and thrombocytopenia.

(1) Appendix 4 N (4).

The course of this form of radiation injury was apparently quite characteristic. The patients became progressively weaker and more apathetic. The severe diarrhea of some, the constant nausea and vomiting, and the anorexia resulted in a clinical picture which was typical. Several contemporary reports mention the haggard facies, sunken eyes and progressive emaciation. Death usually occurred suddenly, apparently with heart failure.

Examples: (1)

Case 6. Araki. Age 41. Female. At the time of the explosion she was nearly in the middle of Okamachi, (2) within 500 meters of the center. She received flash burns on the face and arms; and contusions and abrasions of the legs. At the time of admission (11-12 August) she had a temperature of 39.°C, dysentery-like diarrhea, and an herpetiform eruption about the mouth, which had an unusual odor. On the morning of 13 August her eyes failed suddenly. Kernig's sign, ankle clonus, and opisthotonus were present. Spinal puncture revealed turbid fluid mixed with blood. She died at 1700, 14 August. The autopsy disclosed subarachnoid hemorrhage from several regions, but does not mention trauma as a cause.

Case 8. Iskei. Age 17. Female. At the time of the explosion she was approximately at 1150 meters. She received flash burns of the left arm. In the course of the sickness she developed anorexia, herpetiform eruption about the mouth, fever up to 40°C, cerebral symptoms and loss of eyesight. Petechiae were first noticed on 11 August and later purpuric spots formed generally. Blood examination on 14 August showed: RBC-1.50; Hb.-37%; WBC - 300. She died at 1630, 15 August.

Case 9. Male. Age and distance from bomb not recorded. His only injury was

(1) Appendix 4 N (4)

(2) See Nagasaki City Plan Map.

a small contusion of the scrotum. Fever commenced 11 August, and increased to 40°- 41°C at the time of death. Epilation commenced 14 August, and on the following day petechiae were noted, and an herpetiform eruption about the mouth. Death occurred at 0015, 16 August.

<u>Severe Cases</u>: <u>Early Phase.</u> The clinical manifestations of this group of patients became apparent between the 2nd and 5th week after the bombing. By that time the severely burned and injured patients had died off to a considerable extent so that the physicians were able to devote more attention to purely medical phenomena. Furthermore, the relief activities were better organized and groups of doctors from various medical schools were in Nagasaki to aid in the care of patients and to study the effects of the ionizing radiation. For these reasons much more information is available on the patients whose illness occurred during that time. It is desirable to consider that this class of patients were less severely irradiated than the first group; but since they lived longer manifestations and complications which were just beginning in the very severe group had the opportunity to develop fully. The variety of clinical syndromes which were seen in these patients represented the predominance of one or another type of complication. The most important single difference between the severe and the very severe cases was the tempo at which the manifestations of radiation injury developed.

<u>Onset</u>: Nausea and Vomiting soon after the explosion was experienced by the majority of patients. The time of onset when it was recorded, was in the early afternoon of 9 August,-2 to 3 hours after the bombing. Associated with this was some <u>fever.</u> In the more seriously affected, the nausea and vomiting and some fever continued for several days, then subsided.

The high incidence of nausea and vomiting on the day of the bombing was observed and commented upon by all the Japanese. Some recognized the similarity of this symptom to the nausea and vomiting which occurs frequently in patients receiving intensive roentgentherapy. The majority of the contemporary reports, however, attributed these immediate symptoms to psychic shock, exhaustion and the distressing odor of the dead. The statistical study (Section 9) considered this symptom carefully and found that it had the highest correlation with radiation injury of any symptom investigated.

<u>Course:</u> <u>Latent Period.</u> After the vomiting had stopped, which generally coincided with a cessation of fever, a latent period occurred. Throughout the duration of it, the patients were said to have felt well except for lassitude and anorexia in some instances. It is apparent that the duration of this latent period is of considerable importance and that it probably bears a close relation to the severity of the radiation injury. This fact was not apparent to the Japanese physicians, and therefore no records are available of the length of this latent period in different types of patient. From individual records it is found to be very short in some, and quite long in others. In the typical patient with severe radiation injury it varied from, say 2 to 28 days. The latent period was terminated by the appearance of any one of several symptoms. The order in which these are presented below is based on the results of a study of the number of days between the bombing and the onset of certain symptoms in a group of patients who survived longer than 20 days.

<u>Diarrhea:</u> When it occurred in patients with the severe type of radiation injury, was quite similar to that which affected those with the very severe type. The stool was watery and mucoid and was reported as grossly bloody

in approximately one-sixth of the patients who survived 20 days. The number of stools per day was quite variable. Abdominal cramping and tenesmus were not so severe as in the usual case of bacillary dysentery. For a large group of patients, the mean day of onset was the 16th after the bombing, and the mean duration was 10 days. Among patients whose location would render them the most liable to severe radiation injury, diarrhea was reported by 50% at some time after the bombing. The incidence of diarrhea in the persons least likely to have radiation injury varied from 12% to 30%. With the appearance of diarrhea. The majority of the patients with radiation injury became febrile. The step-like daily increase of the maximum temperature resembled the fever-curves of the enteric fevers and had there not been such abundant evidence for another causation, the majority of experienced clinicians would have diagnosed "typhoid" or "dysentery".

Among the reports received from the Japanese physicians there was one (1) which described bacteriologic and immunologic studies of the diarrhea. Stools of 17 patients were examined, apparently once, and S. dysenteriae (type Shiga) was cultured from one. Serum agglutination reactions were positive against Shiga bacillus in titres in excess of 1:160 in 7 of the 37 patients. In view of the poor quality of laboratory work done in Japan currently, this must be accepted as a minimum estimate. The etiology of the diarrhea has been difficult to determine. There was a large amount of diarrhea reported among the survivors, and the incidence was high (12%) in persons whose position was such that radiation injury seems unlikely. The statistical correlation of diarrhea with such a symptom as epilation was not very great. Opposed to these findings is the evidence of the clinical

(1) Appendix 4 N (13).

records, when diarrhea of a particularly debilitating sort is reported in most patients with the severe type of injury. Regardless of the etiology, diarrhea was one of the earliest and most serious features of the acute type of radiation injury.

Epilation appears to have been the commonest symptom which terminated the latent period, and heralded the onset of the acute symptoms of radiation injury. It was also the clinical symptom most certainly due to ionizing radiation. Among the patients with the severe type of radiation injury, epilation was regularly observed. An inspection of the clinical records indicated a rough correlation between the time of onset of this symptom and the severity of the syndrome that developed. In general, the patients who epilated earliest were the sickest. The mean day of onset for all patients who displayed this symptom was the 21st day after the bombing.

The alopecia which developed was symmetrical, with a tendency for the crown to become epilated earliest. The typical appearance is shown in Figures 34, 35 and 36; and 37; for children, women and men, respectively. The obvious epilation involved the scalp and although the Japanese reported the loss of hair from eyebrows, beards, axillae and the pubis, few indubitable examples were seen by the American Members of the Joint Commission. The Japanese is not very hairy ordinarily, and the only clinical test of roentgen epilation which was valid was the ease with which hairs could be pulled out. This phenomenon was only observed after 1 October in the case of the scalp.

Soon after, or concurrently with the advent of epilation the majority of the patients became febrile. If diarrhea with its fever had preceded the epilation, there was an exacerbation. The pattern of the fever was not characteristic, although a tendency for a step-like daily increase was observed in many patients. The fever curves which were available were of

every type: remittent, intermittent, and continuous, and the variation was so great that no single example can be offered as typical.

In a small number of patients with the severe type of radiation injury, bullae and vesicles appeared on the unburned skin 2 to 3 weeks after the bombing. The likelihood that such lesions were a form of roentgen dermatitis has been suggested. (1) Photographs are available of three examples of this process. The child shown in Figure 38, ultimately recovered after a severe illness. The woman shown in Figures 39 and 40, died about 10 days after the photos were made, with severe radiation disease. The type of necrosis seen in these bullae is shown in Figure 41.

At the time that the fever and epilation occurred, either or both of two very characteristic conditions also appeared: orophayngeal inflammation, and purpura. There was so great a variety of inflammatory processes in the mucous membranes of the mouth, throat and larynx that it is convenient to discuss them jointly. Actually, in most patients the first evidence of these processes was a gingivitis with painful swelling of the gums, frequently associated with some gingival bleeding. From the onset, however, lesions

(1) "Sometimes the acute reaction is of the bullous type with large raised blebs containing abundant serum not infrequently becoming secondarily infected. If the radiation has been very heavy, ulcers, sharply defined and punched out, may appear about 2 months after exposure."

S. Warren, "Effects of Radiation on Normal Tissues". Page 183. Reprint #560, Cancer Commission of Harvard University.

occurred in any part of the oral cavity, the pharynx, the larynx, the nose, etc. With the appearance of such symptoms the fever became even more marked The progress of the oropharyngeal lesions was rapid. From a stage of simple inflammation, the lesions became more extrusive and more painful. A violaceous discoloration was described in many of the records, and ulceration was frequent. In the more severely affected, the ulcerative lesions became necrotic, and the contemporary description used the terms: pseudo-membranous, pseudo-diphtheritic, gangrenous, noma, aphthous, etc., to describe the appearance. Large, sloughing ulcers developed in many cases, and when these extended into the larynx, death from suffocation occurred. In the records of the fatal cases, necrotic ulcerations were a frequent occurrence, while in the reports of the survivors they were less frequent, and only approximately 10% of the most exposed group reported them. Many of the deaths occurred during this stage, and it seems obvious that these severe infections were responsible.

The Japanese physicians who were familiar with agranulocyte angina stated quite positively that this type of lesion was similar in appearance. Most of them also said that the lesions in the patients with radiation injury were more severe and extensive than the ones ordinarily seen with severe leukopenia, due to other causes. It was generally assumed that the nasopharyngeal lesions were of bacterial origin, although there are no records of bacteriological studies. The possibility that a roentgen mucositis or epithelitis was partly responsible for the inceptions of these lesions was suggested by some Japanese workers. At one period, the medical officers of U.S.S. HAVEN, gave the Japanese some penicillin which was used to treat patients with this type of lesion. Defervescence and healing was remarkably prompt; (1) but there

(1) Appendix 4 N (2)

are no data on the dosage, or the infecting organisms. A severe broncho-pneumonia (See Pathology Section) was a frequent complication of these severe ulcero-necrotic processes in the oropharynx and the upper respiratory tract. Among the material from Nagasaki there were very few X-ray examinations or bacteriologic studies of such cases; and the extensiveness of the pulmonary lesions was only apparent at autopsy.

The mean day of onset after the bombing, for oropharyngeal lesions was the 22nd day; and the mean duration of the lesions was from 10 to 12 days. In the most exposed group of patients who lived longer than 20 days, approximately 40% had some type of inflammation in the mouth or throat. Since this group includes many less severely affected cases, the incidence in severe cases was obviously very high.

<u>Purpura</u> (1) appeared in patients with the severe type of radiation injury at about the same time as the oropharyngeal inflammation. Naturally, there was some variation between cases, so that in one patient the one symptom would occur first, and in another the other. Among the severe cases, the majority exhibited both phenomena, while in the milder cases, one or the other might occur alone. Figures 42, 43 and 44 show typical examples of the cutaneous purpura.

(1) Throughout this section, the term <u>purpura</u> will be used to include hemorrhagic manifestations of all types, such as are customarily seen in patients with purpura hemorrhagica. The terms <u>hemorrhagic tendency</u> and <u>hemorrhagic diathesis</u> were favored by the Japanese; but they have restrictive connotations which purpura does not.

The changes in hematologic findings in these patients consisted of thrombocytopenia and alterations in bleeding time and clotting time. The earliest manifestations of purpura were gingival bleeding and petechiae. In cases with marked purpura every known sort of hemorrhagic manifestation was observed. Epistaxis and metorrhagia were especially serious because large amounts of blood were lost, and control was difficult. In many contemporary Japanese reports the statement appears that "every known method of controlling hemorrhage failed". In addition to the obvious manifestations of purpura, hemorrhages occurred in the viscera and the central nervous system which contributed to the symptomatology and the mortality. In general, there does not appear to have been anything unique about the purpura. Physicians with hematologic experience said that it resembled that of benzol poisoning most closely, and was of shorter duration.

The mean onset of purpura was on the 24th day after the bombing; and the mean duration in the most severely affected group of patients was 13 days. The incidence of purpura in the most exposed group of survivors was 28%; which is a low value. (1)

In some of the severeccases where vesicles (2) occurred in the skin pf patients with purpura there was hemorrhage into them and such lesions then broke down and became ulcerative. (See figures 41 and 45.)

Suppuration of wounds and burns which had been healing satisfactorily occurred in the early phase of the acute stage. This appears to have been a rather general occurrence, and it is reported in many of the contemporary

(1) For a complete discussion of the mean onset duration and incidence of symptoms, see the Statistical Section, (9).
(2) Appendix 4 N (1)

reports. The common glass fragment wounds whose tendency was to heal slowly (because the fragments frequently were not removed) were particularly affected. These lesions became severe necrotic, often ecthymatous ulcers at this time (figure 45) and undoubtedly contributed greatly to the septic state of the patients.

The blood picture during the acute or early phase of the severe type showed striking changes with leukopenia, and thrombopenia. Anemia was less marked, although the serial studies showed a steady decrease in red cell count. The changes in the blood are described in detail in the Blood Section (5).

An example of a typical fatal case of the severe type of radiation injury is presented. It is a synthesis of several incomplete records:

Case X; Age ?. Was less than 1000 meters from the center. He received no burns or mechanical injuries. Nausea and vomiting occurred on the day of the bombing and persisted for several days. He then felt fairly well for the next 7 or 8 days, when a diarrhea commenced, associated with moderate fever. On the 12th day after the bombing his gums became painful and his throat sore. On admission to hospital he was febrile (38.5°C) and the cervical lymph nodes were slightly swollen and tender. He noticed epilation for the first time. The following day gingival bleeding and epistaxis occurred and petechiae were found in the skin of the legs and arms. The diarrhea became more severe. His temperature was increasing steadily. During the next few days, his gums and throat became ulcerated and swallowing was almost impossible. Meanwhile, purpuric spots appeared generally and gross hematuria was noticed. On the following day his vision suddenly became dim, and delirium occurred. His fever was continuous, varying from 40° - 41° C. He died suddenly on the

18th day after the bombing. The clinical picture which has been presented thus far may be considered the early, or acute phase of the severe type of radiation injury. Many patients died within a week or two of the onset of some or all of the symptoms mentioned. Of this group we know only little, clinically, although since many came to autopsy, there was abundant pathological material. The patients who survived two to three weeks in spite of the lesions described generally went on to recovery. These patients were rather thoroughly studied during convalescence; and most of the studies by the Japanese, and all the studies by the American doctors were performed on them, as well as on the moderately severe and mild cases. In many of the Japanesereports all the survivors are grouped together and a presentation of the courses of the various types of radiation injury (i.e. severe, moderate, and mild) is difficult. Unfortunately, the same lumping together of all survivors has been practiced in the statistical study of the questionnaires. Nevertheless, there were differences which we shall attempt to present.

Severe Cases: Late Phase.

The convalescence of patients with severe radiation injury began rather suddenly, and in general coincided with an increase of the leukocyte count which occurred in the 5th - 6th week after the bombing. Defervescence appears to have been rapid; and in the course of 2-3 weeks the ulcerating lesions in the oropharynx and the skin healed. Wounds which had been suppurating displayed the same tendency to improvement. The purpura subsided, and fresh petechiae and new episodes of hemorrhage did not occur. There does not appear to have been much change in the epilated skin during the first 2-4 weeks of convalescence, and only a few contemporary reports describe the regrowth of hair at this time. The red blood cell count reached the lowest

value on an average, during the early weeks of convalescence (7th - 8th week after the bombing). In some patients whose acute course had been particularly stormy, the coincidence of anemia and an intercurrent infection was often fatal. The majority of the infections which occurred at this time were of the respiratory tract, and in spite of a fair leukocyte response, some patients died with pneumonia.

It is difficult to generalize further about the course of patients during convalescence for the rapidity of their recovery depended on a variety of factors, the more important of which were: the severity of the radiation injury; the severity of the associated injuries and infections; the degree of emaciation and debility that had developed during the acute illness, etc. The younger patients, and those with few or mild associated injuries usually improved slowly but steadily, so that by mid-October (i.e. 10th week) the majority were sufficiently recovered to leave hospital, and to resume their habitual occupations. A summary of the clinical record of a typical case is presented:

Case 3054, K. Matsuo, Age 49, Male, 1200 meters.

Patient was standing outdooors behind a wall, and received a minor 2nd degree burn of face and neck. Nausea and vomiting occurred only on the day of the bombing. He remained fairly well, except for the burns until 22 August (13th day) when gingivitis developed. Epilation was first noticed on 23 August and hair continued to fall out until 10 September. Purpura commenced 5 September, but was not very severe. Pharyngitis, which was quite severe started on 7 September. The ulceration healed within 10 days; but soreness was still present in October.

Examination of Blood:

Date	Hb	RBC	WBC	BLEEDING TIME
8 September	60%	3.30	500	12' 00"
13 "	55%	2.20	1100	10'00"
20 "	50%	2.60	3600	6'00"
12 October	78%	-	6900	-
25 "	-	-	6150	-
5 November	94%	-	8900	-

One characteristic group of patients was studied who had survived the early or acute stage of severe radiation injury, but in whom convalescence did not occur, on the usual sense of the word. The oropharyngeal lesions, and the purpura disappeared, and the fever subsided; but a steadily progressive cachexia developed. The clinical findings in 15 such cachectic patients are described in a report by Urabe and Menjo (1).

The typical features of the syndrome were: progressive anemia; chronic diarrhea; hypoproteinemia, with mutritional edema; and extreme emaciation. 7 of these patients died and were autopsied during the period of study by the Joint Commission. Complete autopsy protocols are filed in the Army Institute of Pathology, (Accession Numbers 158930--184, 190, 192, 193, 194, 195, 196).

Moderately Severe Cases.

This type of the syndrome of radiation illness occurred frequently in people who were farther than 1500 meters from the bomb. There were also many cases in the occupants of the reinforced concrete buildings of the Hospital of the Nagasaki Medical College. The incidence of any of the specific

(1) Appendix 4 N (24)

symptoms of radiation injury was about 2/3 of the frequency in patients with the severe type. Epilation appeared in the moderately severe cases on an average in the 3rd week after the bombing. It was less complete than in the more heavily irradiated patients, and the regrowth of hair was evident early in convalescence. The majority of such patients experienced nausea and vomiting shortly after the bombing, but the symptom seldom persisted after the first day. The latent period before the onset of typical symptoms was protracted, and varied from 2 to 4 weeks. During this time, diarrhea was reported by a portion of the patients but the available descriptions suggest a mild type in comparison with that which occurred in the more severely injured. Oropharyngeal inflammations usually terminated the latent period but these were mild, and although painful, swollen lesions occurred, ulceration was the exception. The course of these lesions was short, and the amount of fever that accompanied them was seldom of high degree or long duration. Purpura occurred in many, but the manifestations consisted generally of gingival bleeding and some petechiae. Wound infection was common, but was of moderate severity. The degree of leukopenia which was recorded was variable, but it seems correct to say that in most patients the white cell count was not less than 1500 per cubic millimeter. The constitutional, or subjective symptoms of malaise, anorexia, lassitude, headache, etc., were more apparent, and often more distressing than the specific symptomatology. Good examples of the course of patients with the moderately severe type of radiation injury are to be found in the eye witness accounts, (13) and (18) Appendix 3 N.

Mild Cases: Patients with the mild type of the syndrome of radiation injury were generally farther than 1500 meters from the center, or were in well shielded locations. The specific symptoms of radiation injury: epilation,

purpura, oropharyngeal inflammation, and nausea and vomiting on the day of the bomb, either did not occur, or occurred singly and in a very mild form. The recognition of this class of patients depended to a large degree on whether or not a leukocyte count was made at an appropriate time. This kind of patient had leukopenia ranging from 2000 to 4000 w.b.c. during the 4th to 6th week after the bombing. In addition to the leukopenia and the occasional incidence of a specific symptom, a variable number of constitutional symptoms or complaints occurred. Malaise, easy fatigue, anorexia and headache were common in this type of patient. A moderate degree of anemia occurred, and it seems reasonable that many of the complaints were due to this. These patients began to feel better after the 6th to 8th week, and by the time the Joint Commission arrived in October, most had made good recoveries, both symptomatically and to some extent, hematologically. Typical examples of the mild form are to be found in the eye witness accounts: (14) and (19), Appendix 3 N.

Special Studies: A detailed description of the manifestation of radiation injury on the various regions and functions of the human body would prolong this section to an undesirable extent. Many studies of special features of radiation injury were carried out in Japan and some of these contributed considerably to an understanding of the clinical syndrome.

Eyes: Members of the Eye Clinic of the Kyushu Imperial University were in Nagasaki from 24 August on. Their report[1] of the type of ocular injuries is the only contemporary one available. The burns and traumatic injuries to eyes were of the sort that would be expected. Lesions attributable to

(1) Appendix 4 N (7).

radiation injury were described in a second report. (1) They stated that retinal hemorrhages were not observed before the 10th day after the bombing. After that time purpuric lesions were also seen in the lids and the subjunctival tissues. At some time subsequent to the 15th day they examined the fundi of 155 patients with the clinical symptoms and laboratory findings of radiation injury. Of these, 22, or 14% were found to have retinal hemorrhages. An excellent water-color painting of the retinal lesions in one of their patients is reproduced as Figure 46.

At a later date, between 20 September and 6 October, Major John J. Flick, M.C. A.U.S. examined the eyes of a number of patients with radiation injury. (2) The incidence of hemorrhagic retinitis is not given in his report, but the details of the lesions in 46 patients are presented. The typical lesion observed, and the frequency of their occurrence is shown in Table 13. This is a very useful report with case histories of illustrative sketches.

TABLE 13

INCIDENCE OF RETINAL LESIONS

TYPE	PER CENT OF PATIENTS WITH RETINAL PATHOLOGY*
Exudates	65.2
Flame hemorrhages	54.3
Pre-retinal hemorrhage	23.9
Roth-type hemorrhage	8.6
Vitreous hemorrhage	4.4

(1) Appendix 4 N (8)
(2) "Ocular Injuries Produced by the Atomic Bombing at Nagasaki" by John J. Flick, Major, M.C. filed at Army Institute of Pathology, Accession #158930

*Percentages add up to more than 100% because more than one type of lesion occurred in some patients.

Ears, Nose, Throat: Dr. Kashiwado [1] examined the ears, nose and throats of approximately 150 inpatients and 50 outpatients who were convalescent or recovered from radiation injury. A small percentage complained of dryness of the nose since the bombing. There was no evidence that such a condition was due to irradiation.

An interesting clinical report of two sisters who developed laryngeal involvement as a feature of the oropharyngeal inflammation stage of radiation injury, was prepared by Dr. Sasaki and his associates.[2] Tracheotomy was necessary in each case; although in one child there was laryngeal edema, while the other developed a severe necrotizing ulceration. Colored illustrations of the pathologic lesions which accompanied the report are shown in Figures 47 and 48. These are the only good pictures of the type of lesion that occurred in the mucosa membranes of patients with radiation injury.

Cardio-vascular System: The report of the I Medical Clinic (Dr. Misao, Chief) [3] includes some studies on the cardiovascular system. Systolic murmurs, and accentuation of the 2nd pulmonic tones were observed in about 1/4 of the inpatients with radiation disease. The murmurs were the typical "hemic" murmurs. Disturbances of the cardirc rhythm were not encountered. Electrocardiograms were made on 45 patients with various types of radiation injury. The abnormalities observed were:

(1) Appendix 4 N (28)
(2) Appendix 4 N (9)
(3) Appendix 4 N (3)

a) Low T-waves (but the report does not indicate how low, or in which leads.)

b) Depression of S-T segment (Same comment as in a.)

c) Left axis deviation (but the report does not give the amount.)

The frequency of these changes in the ECG varied directly with the apparent severity of the radiation injury, as judged from the leukocyte count, and the hemoglobin value.

Gastro-intestinal System: The secretory activity of the salivary glands was studied by Misao's group (1) and the ptyalin content of saliva was within normal limits in 14 patients. Pancreatic function was studied by Sawada's group (2) and the diastase activity of the urine was normal in the 17 patients with radiation injury. A number of clinics reported urinalyses for sugar, all of which were negative. In one group of 13 patients (3) studied by Dr. Hirohata, the fasting blood sugar was normal, varying from 81-119 mg.%. Gastric secretions were studied in several clinics, and a small percentage of anacidity was found. Kishimato studied 20 patients at Omura Naval Hospital using histamine as a stimulating substance. He could find no evidence of altered secretion of HCl. He also performed gastroscopic examinations and fluoroscopic studies, all of which were normal.

Hepatic function was the subject of a number of studies. The methods used were not the most modern, and the studies were inconclusive. Elevation of the icteric index was observed in only 1 of 17 patients with a variety

(1) Appendix 4 N (3)
(2) Appendix 4 N (1)
(3) Appendix 4 N (14)
(4) Appendix 4 N (29)

of types of radiation injury with a variety of types of radiation injury. (Sawada study). Urobiligen excretion in urine was studied in many clinics, but the reports are contradictory. The techniques used for this, and other liver function tests were not reliable.

Genito-Urinary System: Urinalysis was performed in most clinics, and a varying number of patients were found to have albuminuria. At Omura Naval Hospital (1) 17% of the patients with radiation injury had albuminuria, usually graded 1 plus or 2 plus (on a scale of 0 to 4). Considering the high incidence of infection in all patients, this does not seem excessive. Microscopic examination of the urinary sediment was not remarkable. Renal function was tested by a concentration-dilution technic by Yamamura[2] and reduced "function" was found in a few older patients.

No studies of the male reproductive system were conducted in Nagasaki. Changes in menstruation were studied by a group headed by Kaida . The degree of disturbance varied inversely with the distance from the bomb. The extent of menstrual disturbance reported by Kaida is not confirmed by the Joint Commission's statistical study. (Section 9). The effects of the bombing on pregnancy was also studied by Kaida (3) with the collaboration of the local obstetricians and midwives. Pregnant women did poorly after exposure to ionizing radiation in large doses.

(1) Appendix 4 N (34)
(2) Report on file at Army Institute of Pathology, Accession No. 158930.
(3) Appendix 4 N (30), (31).

Biochemical Studies: Hirohata at Kyushu Imperial University performed many chemical studies on the blood of 32 convalescents.[1] The most striking features were:

a) Reversal of albumin:globulin ratio, with persistently low values for plasma albumin.

b) Normal values for fibrinogen, globulin, NPN, Urea N, sugar.

c) Low values in some patients for serum calcium. This finding was not associated with low values for plasma proteins.

The only other chemical studies recorded were estimates of the vitamin C saturation, done by Sawada's group.[2] The evidence for vitamin C deficiency appears to be good.

(1) Appendix 4N (14)

(2) Appendix 4N (1)

S U M M A R Y

1) The precise incidence of radiation injury is not ascertainable.

2) At a distance of 1000-1100 meters from the center, persons surely exposed to ionizing radiation had a 50% chance of surviving.

3) On the basis of the available clinical records and the questionnaire study, it is possible to describe the clinical syndrome of radiation injury in terms of a group of specific laboratory findings and clinical symptoms. The symptoms were:

a) Nausea and vomiting on the day of the bombing.

b) Epilation.

c) Oropharyngeal inflammatory lesions.

d) Purpura.

When laboratory studies were made at appropriate intervals of time after exposure changes in the blood were found, consisting of:

e) Leukopenia

f) Anemia

g) Thrombocytopenia

In any group of patients the intensity and the incidence of these findings was in direct proportion to the amount of ionizing radiation received. These observations which are based on a study of Japanese injured by atomic bombs provide a sound basis for the diagnosis of the syndrome of radiation injury, and for an estimate of its severity.

4) An important aspect of the clinical course was the tempo at which the specific symptoms appeared after irradiation, and the rapidity with which the pathological processes evolved. In general, it appeared that the more

rapid the progress of the disease, the more severe was its manifestations, and the graver the prognosis.

5) In addition to these specific manifestations the patients complained of a large number of varied symptoms. Of these, diarrhea was the most important and troublesome, both to the patient and from a diagnostic standpoint. There is little reason to doubt that exposure to ionizing radiation in suitable amounts can cause a severe, even bloody, diarrhea. The circumstances in Nagasaki were such that the high incidence of diarrhea in people with no evidence and little likelihood of radiation injury, rendered the symptoms of little value in diagnosis. The other symptomatology complained of by the patients was of a non-specific nature, or due to complications.

(6) On the basis of such tests as were used, the doses of ionizing radiation which were not fatal did not cause continuing demonstrable disturbances in the physiological functions of the cardiovascular system, the gastro-intestinal system (excepting the diarrhea); and the genito-urinary system (excepting the damage to the gonad).

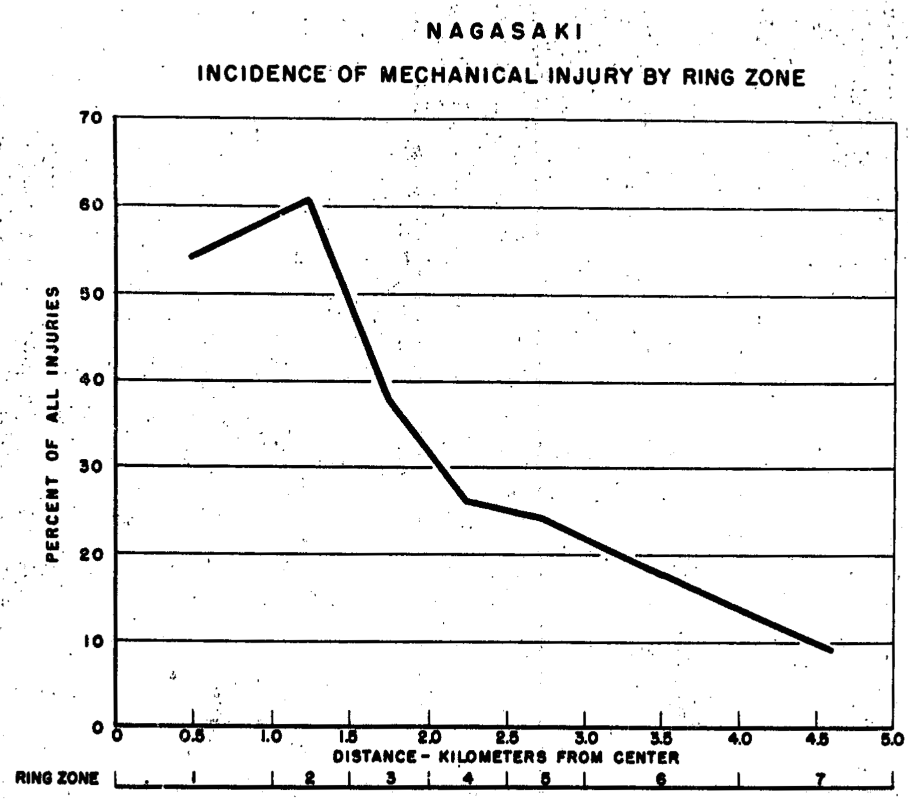


Fig. 1 (5N)--Graph showing percentage of survivors in each ring zone who sustained mechanical injuries. (Photo File #NP 167.)

Fig. 2 (5N)--Photograph of a board fence and a pole at about 1200 meters from the center. Notice: a, the unscorched "shadows" cast by the grass and weeds; b, the typical sharp profile of a flash burn on the pole; c, the small stick which has been driven into the board by the air blast. Had it been there before the flash of the explosion there would be a shadow of it. (Photo File #NE 100c.)

Fig. 3 (5N)--Typical scene inside the Morimachi plant of the Mitsubishi Steel and Arms Works, at 1300 meters, showing the type of damage responsible for injuries. This was the casting shop: One-half the workmen here were casualties, and of those who were not killed outright, 80% received mechanical injuries. (Photo File #NB 436.)

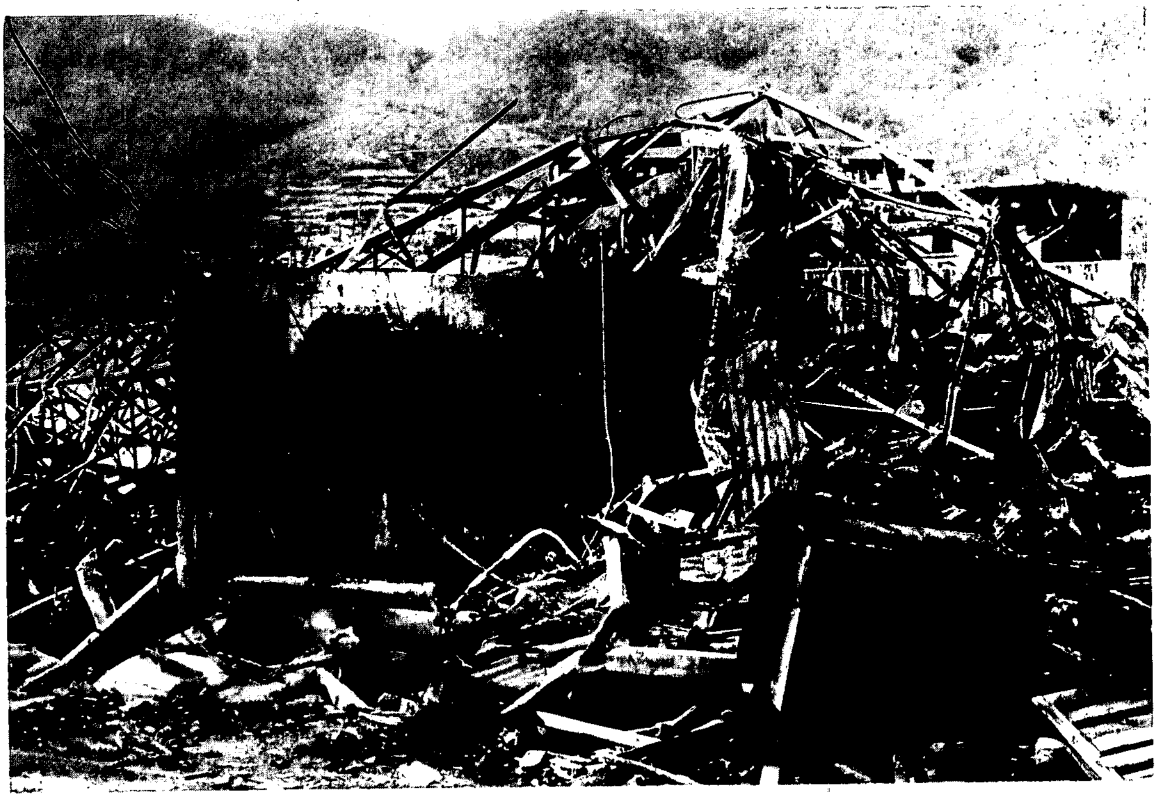


Fig. 4 (5N)--Mitsubishi Arms Factory, 1100 meters. Type of damage that occurred to light concrete, steel-framed buildings. Notice the corrugated sheets from the roof, which caused serious wounds. (Photo File #NB 438.)

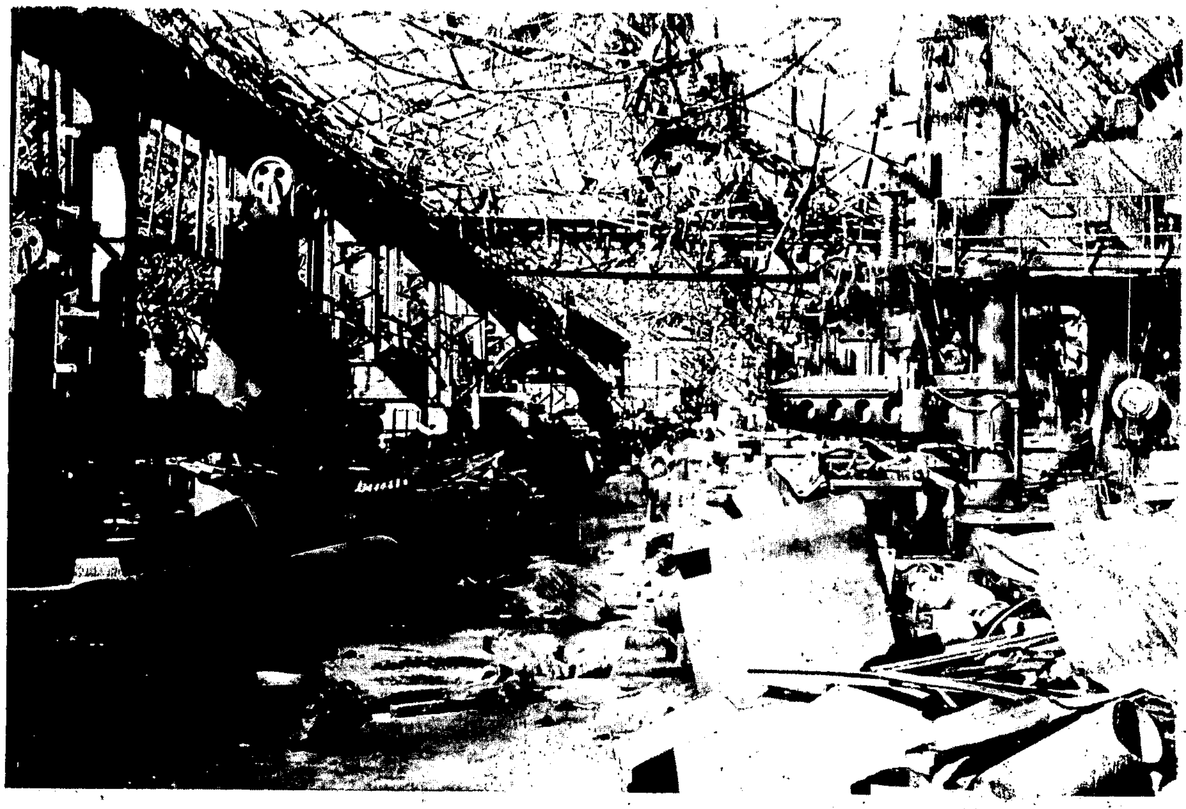


Fig. 5 (5N)--Scene inside a heavy machine shop of the Mitsubishi Steel Factory, 700 meters. 70-80% of the workmen in this building were killed, and of the survivors, the majority had received mechanical injuries. (Photo File #NB 458.)

Fig. 6 (5N)--Keiho Middle School, at a distance of 1000 meters. This shows the typical debris that remained after the demolition of a large timber-framed building. Notice that the wood had not burned and that the majority of the roof timbers are quite heavy beams. Virtually every person in this building was injured, but the number said to have been killed instantly was small. (Photo File #NB 416.)

Fig. 7 (5N)--Chinzei Middle School, at a distance of 500 meters. The view shows the wreckage of the 3rd and 4th floors which collapsed. This reinforced concrete building was heavily damaged, and there were no survivors on the 2nd, 3rd, or 4th floors. (Photo File #NB 414.)

Fig. 8 (5N)--Surgical Clinic of the Hospital of the Nagasaki Medical College, at 800 meters. Scene is a ward on the 1st floor of a reinforced concrete building, showing how the heavy plaster interior trim has fallen from the walls and ceilings. The bed patients were trapped under this debris, and many were burned to death before they could be rescued. (Photo File #NB 402)

Fig. 9 (5N)--Yamazatomachi, a residential section, just beneath the point where the bomb exploded. Notice that the trees and poles are standing, but with branches and cross-arms stripped off. The complete demolition of houses is shown. Notice that all the debris did not burn. There are no known survivors from this district except people who were inside cave-shelters. (Photo File #NG 168.)

Fig. 10 (5N)--Shireyamamachi, municipal tenement district, 700 meters, showing the demolition of Japanese type houses. The appearance is very like that seen in the wake of a tornado or a hurricane. The few buildings that are standing were built after the bombing. Notice that fire does not appear to have occurred here. 90% of the residents of this district were killed. (Photo File #NG 174.)

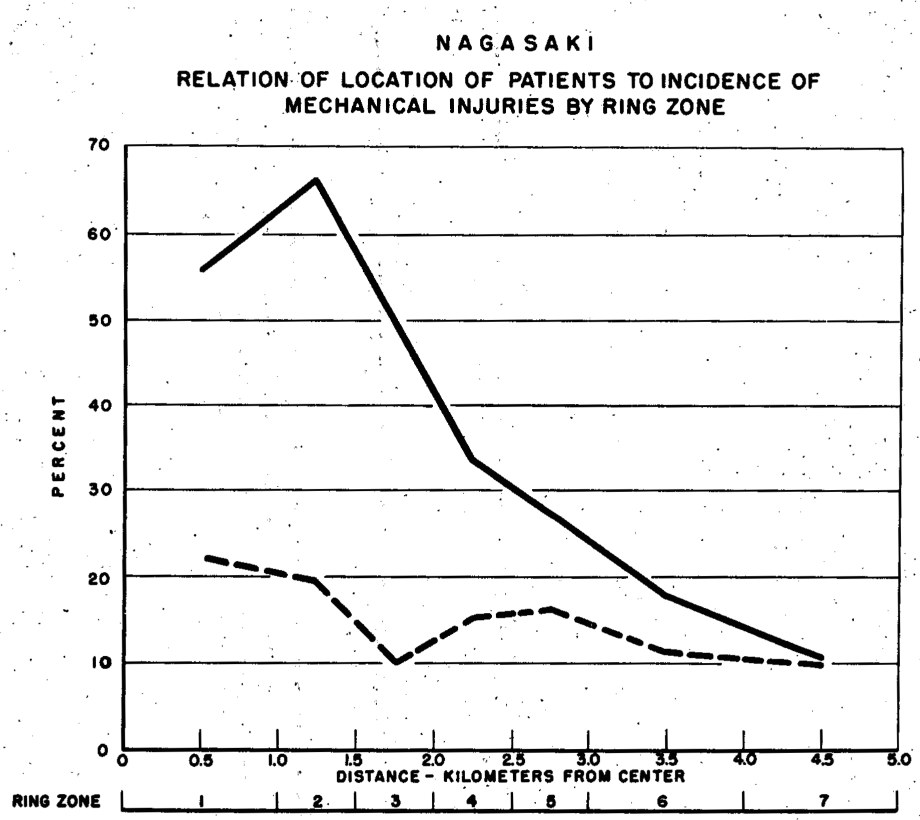


Fig. 11 (5N)--Solid Line: Percentage of people who were inside wooden buildings and who received mechanical injuries. Broken Line: Percentage of people who were outdoors, unshielded, and who received mechanical injuries. (Photo File #NP 168.)

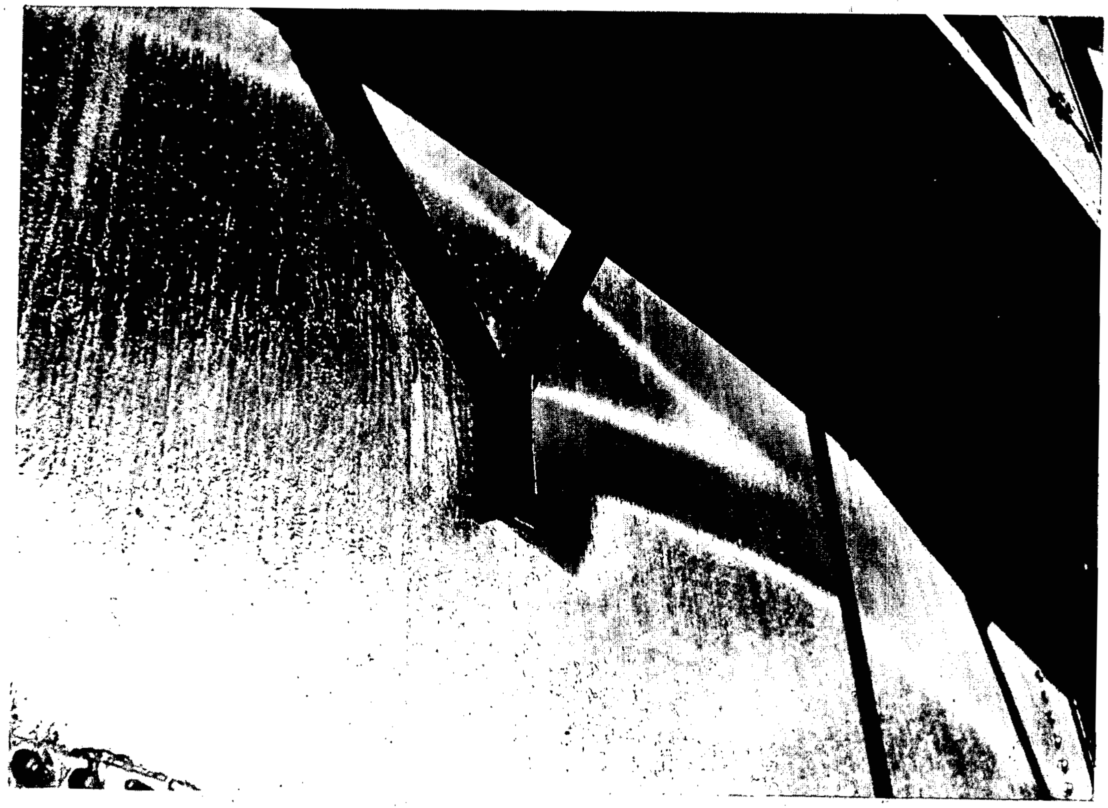


Fig. 12 (5N)--"Shadow" effects on the painted surface of a gas storage tank, 1500 meters. The radiant heat has glazed the paint that it is shiny in comparison with the dull surface which was in the shadow of the support. The black shadow to the left of the support is caused by sunlight. The indefinite border of the glazed area may be a penumbral effect. (Photo File #NE 104.)

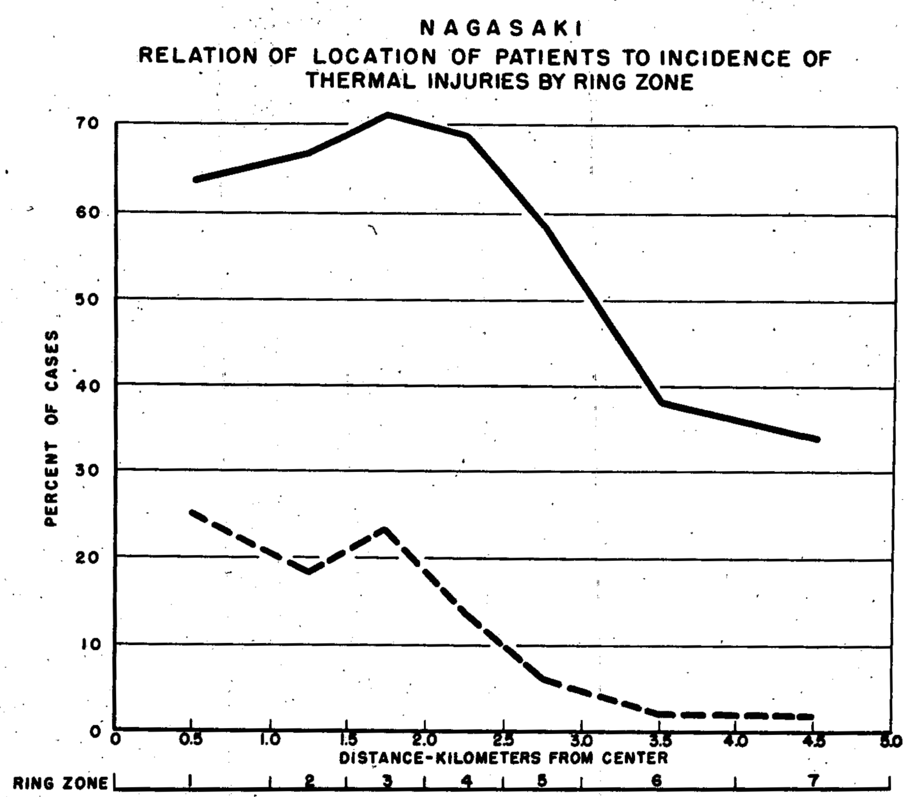


Fig. 13 (5N)--Solid Line: Percentage of people who were outdoors, unshielded, and who received burns. Broken Line: Percentage of people who were inside wooden buildings and who received burns. (Photo File #NP 169.)

Fig. 14 (5N)--Kunimoto, 19, Male. Distance unknown. This man was dead on arrival at hospital, approximately 12 hours after the bombing. Notice the extensive 2nd and 3rd degree burns of exposed skin, with charring, exfoliation, and vesicle formation. Burns of this severity were said to have occurred within 1000 meters. 10 August 1945. Omura Naval Hospital Photo. (Photo File #NP 153.)

Fig. 15 (5N)--Akiyama, 60, Female, 500 meters. Died 15 October 1945. This patient was prone in the open. She was burned on exposed skin, as well as on skin covered by clothing. This picture was made by the Japanese in late August. The burns shown healed slowly, but she died from radiation injury. Omura Naval Hospital Case No. 3098. (Photo File #NP 105 b; AMM Accession 158930-193.)

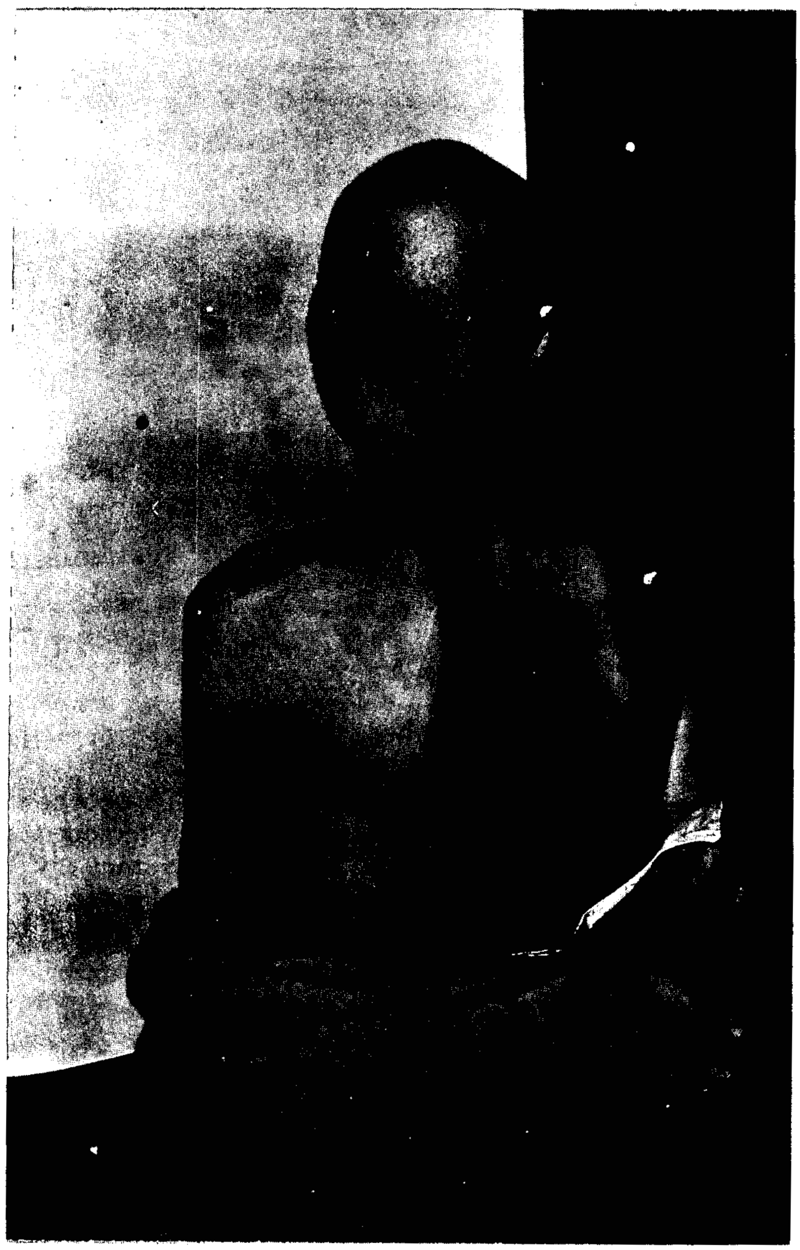


Fig. 16 (5N)--Fukabori, 34, Male. 800 meters. This patient was sitting inside a wooden house. He received 2nd degree burns of the left side of his face and neck, left foot, and both hands. Notice: a, epilation of scalp; b, depigmentation of the healed burn; c, zone of hyperpigmentation between burned and normal skin; d, the cauliflower ear, a healed perichondritis, secondary to the burn. 11 October 1945. Omura Naval Hospital Case No. 3211. (Photo File #NP 103.)

Fig. 17 (5N)--Kasasa, 48, Male. 900 meters. This man was standing in the position shown, facing away from the bomb. The air-burst occurred just behind and above his head. He was wearing heavy cotton military-type clothing which was scorched and destroyed by the radiant heat. He developed very mild symptoms of radiation injury in addition to burns. See Figure 18 (5N). Shinkozen Hospital Case No. 1396. (Photo File #NP 123 b.)

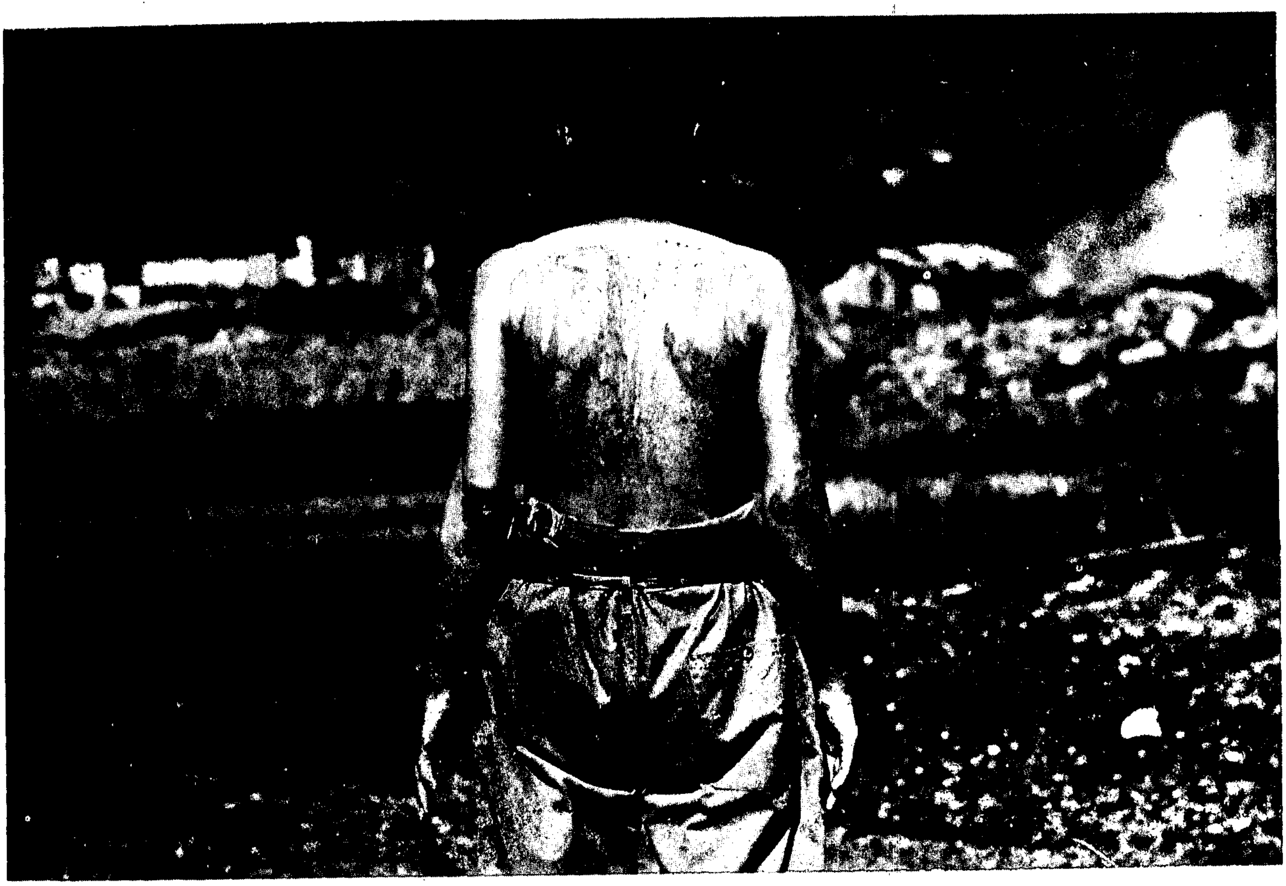


Fig. 18 (5N)--Kasasa, 48. Male. 900 meters. This photo shows healed 2nd degree burns that occurred beneath a heavy cotton khaki shirt. Notice the zone of hyperpigmentation between the healed and the intact skin and the depigmentation of most of the burned area. There is some keloid formation on the elbows. November 1945. Shinkozen Hospital Case No. 1396. (Photo File #NP 123a.)

Fig. 19 (5N)--Maeda, 19, Male. 1000 meters. This patient was standing outdoors. The burns on the back and arms were received underneath a white shirt. Notice the depigmentation of the healed skin in comparison with the intact skin and the zone of hyperpigmentation between burned and healthy skin. There is also keloid formation on the right elbow and a healed perichondritis of the left ear. October 1945. Omura Naval Hospital Case No. 3157. (Photo File #NP 160.)

Fig. 20 (5N)--Fukabori, 26, Female. 1200 meters. This patient was sitting inside a wooden house by a window. She received 2nd degree burns of the exposed skin of face and neck (notice the collar line of her blouse) and also severe burns of her legs which were covered by long khaki trousers. Notice the combination of pigmentation and depigmentation of the healed burns of legs and feet. 11 October 1945. Shinkozen Hospital Case No. 409. (Photo File #NP 117a.)

Fig. 21 (5N)--Fukabori, 26. Female. 1200 meters. Close-up view of face and chest of patient shown in Fig. 20 (5N). Notice the depigmentation of the burned skin of face and neck and the zone of hyperpigmentation. The skin of the chest, protected by her shirt from the radiant heat, is a dirty brown color. This appeared subsequent to the bombing and had the appearance of roentgen pigmentation. 11 October 1945. Shinkozen Hospital Case No. 409. (Photo File #NP 117b.)

Fig. 22 (5N)--Matsuo, 22. Female. 1300 meters. This patient was sitting outdoors and received 2nd degree flash burns of the exposed skin of face, neck and forearms. The burns of the arms and shoulders occurred under dark-colored clothing. Notice the variations in the pigmentation and depigmentation of the healed burns. The bandage covers a healing perichondritis, right ear. 11 October 1945. Omura Naval Hospital Case No. 3235. (Photo File #NP 108.)

Fig. 23 (5N)--Nonaka, 23. Male. 1400 meters. This man was standing outdoors wearing only trousers. He received 2nd and 3rd degree burns of the exposed skin. Notice: a, the keloid formation on neck and shoulders; b, the variations in pigmentation--in general the severely burned skin is depigmented. This is quite obvious in the case of the right nipple. The skin which was slightly burned is pigmented. 11 October 1945. Omura Naval Hospital Case No. 3209. (Photo File #NP 103a (K).)

Fig. 24 (5N)--Akase, 15. Female. 1400 meters. This patient was standing outdoors wearing green-colored clothing. She was burned on all exposed surfaces and on her back underneath her clothing. The burns on the feet, which were bare, and the ankles are quite typical. The dark color of the unburned skin is partly due to the lighting. The record does not state that the skin of this patient was darker in color after the bombing. The burns shown were healing, and she ultimately recovered. Japanese photo, August 1945. Omura Naval Hospital Case No. 3140. (Photo File #NP 131.)

Fig. 25 (5N)--Toragoro, 44. Male. 1600 meters. This man was facing the center of the explosion. The burns on his chest and arms occurred under clothing. Notice the marked pigmentation of all the healed skin. The contrasts of pigmented burned skin and the unburned "shadows" on the face constitute the "mask" seen on many patients. Notice the hyperpigmented zone on the neck between the burned and healthy skin. October 1945. See Appendix (3N) 14. (Photo File #NP 124b.)

Fig. 26 (5N)--Tamiguchi, 17. Male. 2000 meters. This patient was standing outdoors and received this extensive burn under his clothing. His shirt "burst into flames," which undoubtedly accounts for the severity of the lesions shown. Notice the irregular area of burned skin on the neck, possibly caused by wrinkles formed when he turned his head. October 1945. Shinkozen Hospital Case No. 427. (Photo File #NP 120b.)

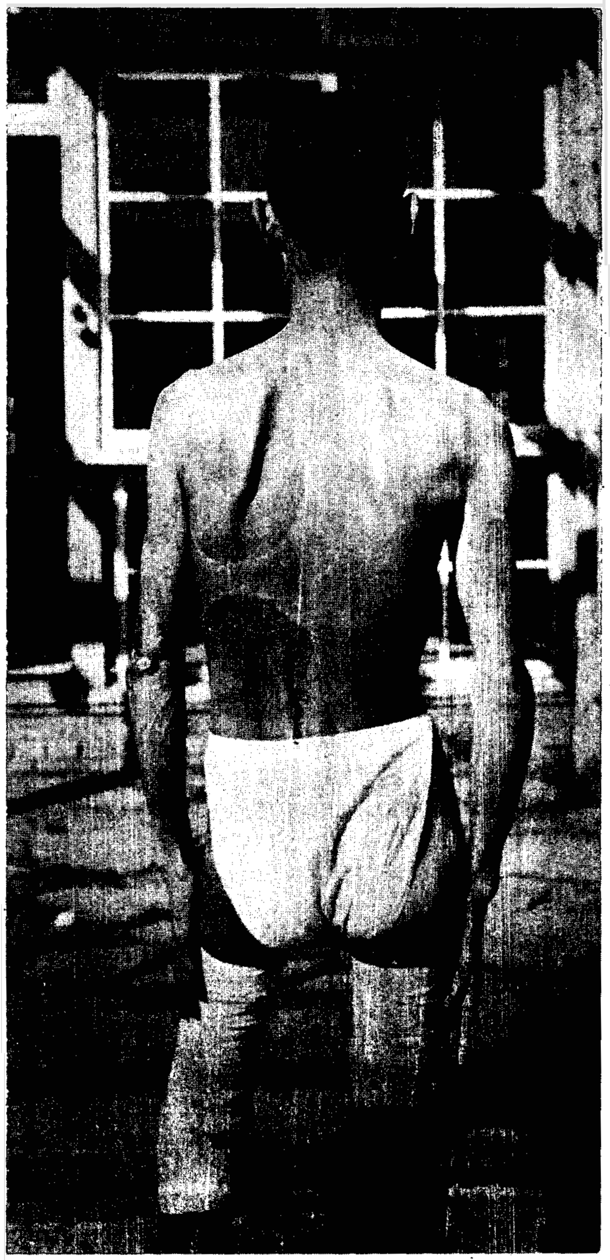


Fig. 27 (5N)--Kinoshita, 19. Male. 2 00 meters. This patient was prone outdoors. The burns on his back were received under light-colored clothing. The cause of the unburned "shadows" on the left arm and the left loin is not known. Notice the pigmentation of the healed burn in comparison with the intact skin. Some of this color is due to hyperemia of the healing skin. There is a narrow zone of depigmentation surrounding the burn. 11 October 1945. Omura Naval Hospital Case No. 9. (Photo File #NP 119.)

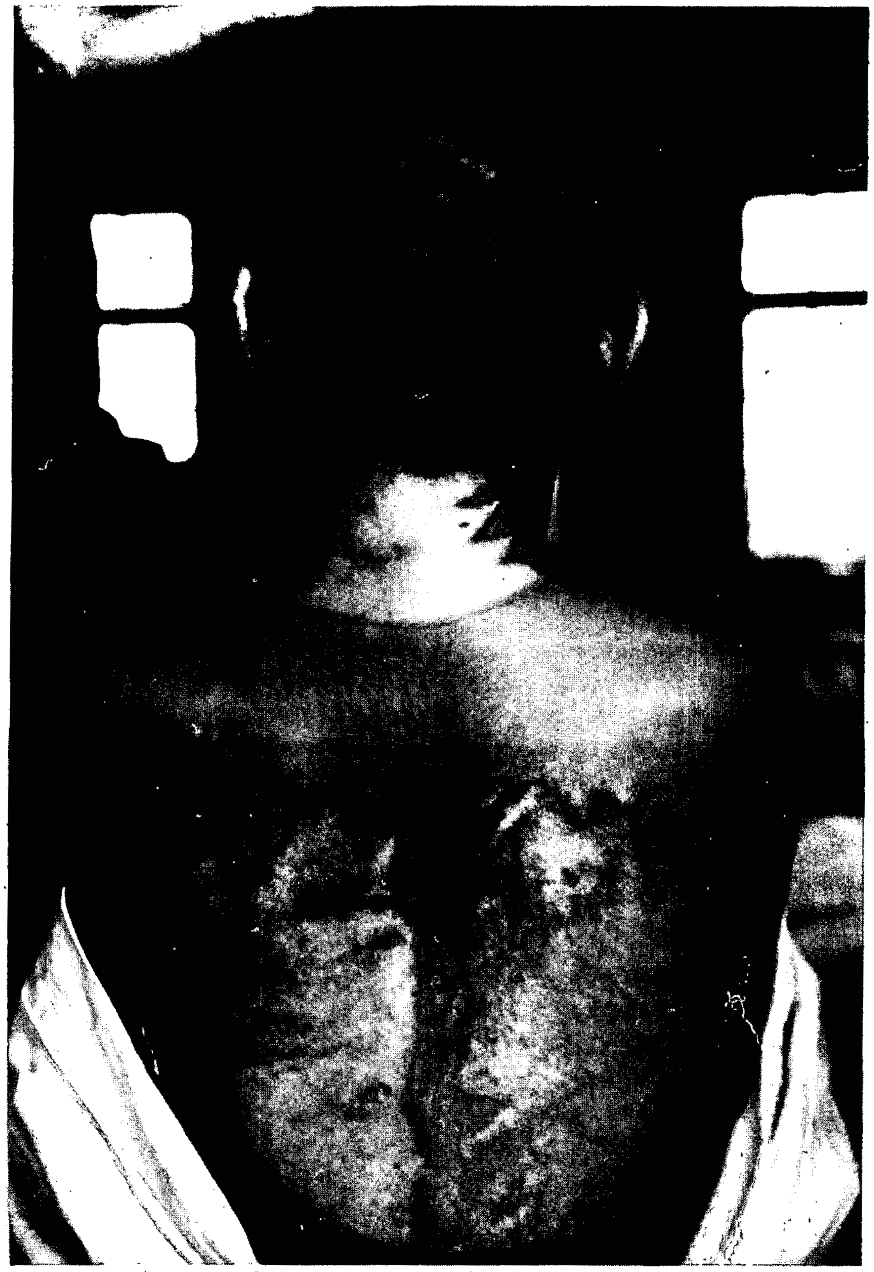


Fig. 28 (5N)--Tsuyama, 15. Male. 2200 meters. This boy was burned on the exposed skin of face and neck and underneath the white shirt he was wearing. The irregular margin of the healed burn of the neck coincides with wrinkles formed when he looks upward and to the right. Notice the depigmentation of the healed skin and the zone of hyperpigmentation that outlines the burn. November 1945. Omura Naval Hospital Case No. 3399. (Photo File #NP 121.)

Fig. 29 (5N)--Kanemura, 30. Male. 2400 meters. This man was standing outdoors wearing a white sleeveless shirt and trousers. The distribution of the burn in relation to the shirt is evident. The healing skin is darker in this picture than the normal skin. In the Kodachrome print it is seen that some of this is due to hyperemia, or at least redness--some of which may be pigmentation--of the burned skin. The pigmentation is particularly apparent in the mask configuration of the burn of the face. 11 October 1945. Omura Naval Hospital Case No. 3030. (Photo File #NP 111c (K).)

Fig. 30 (5N)--Iruyama, 33. Male. 2400 meters. This patient was standing outdoors and was burned only on exposed, uncovered skin. The photograph shows keloid formation and irregularity in the pigmentation of the healing skin. 11 October 1945. Omura Naval Hospital Case No. 3189. (Photo File #NP 114a.)

Fig. 31 (5N)--Shiozaki, Age 15. Male. 1300 meters. This patient was inside a concrete building, the interior of which was demolished and then caught fire. He was wearing shoes and gaiters, but received 3rd degree burns on the legs escaping from the building. The changes in the pigmentation of the healing skin and keloid formation are shown. 11 October 1945. Omura Naval Hospital Case No. 3194. (Photo File #NP 100.)

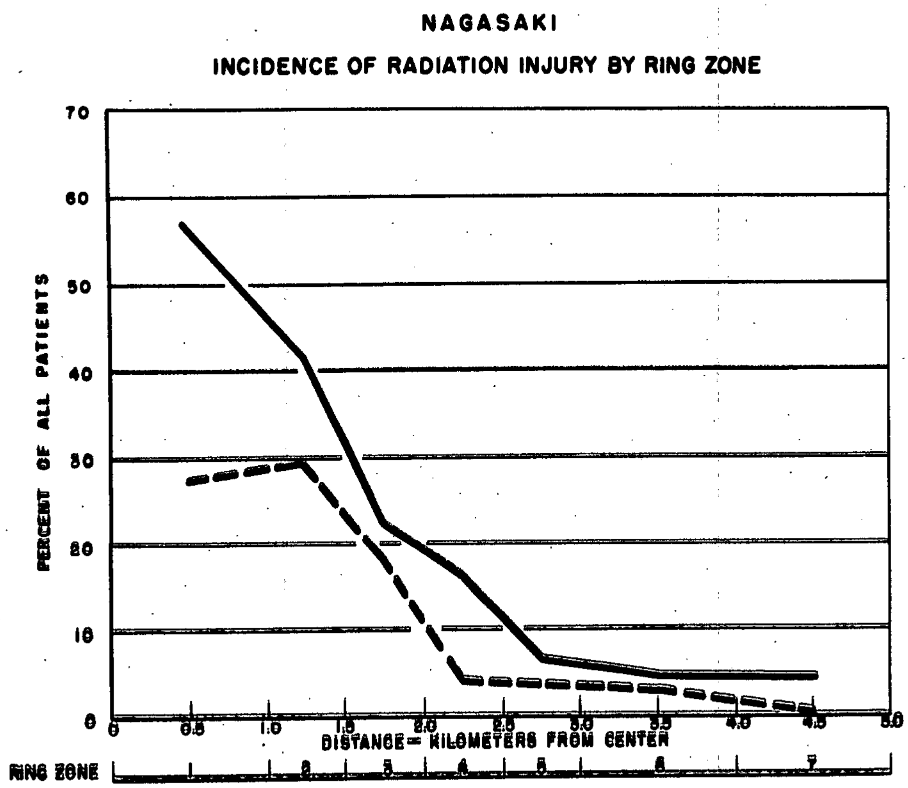


Fig. 32 (5N)--Solid Line: Percentage of people who were outdoors, unshielded, or inside wooden buildings, who received radiation injury. Broken Line: Percentage of people who were inside heavy (concrete, brick, factory-type) buildings, who received radiation injury. (Photo File #NP 170.)

Fig. 33 (5N)--Kosumi, 48. Female. Distance unknown. This is the body of a patient who died during the 2nd week after the bombing. In addition to the flash burn of the face, the photo shows lesions about the mouth which commenced as an herpetiform eruption which later became necrotic. Japanese photograph. Omura Naval Hospital. (Photo File #NP 151.)

Fig. 34 (5N)--Photograph of three siblings who were at the same (unspecified) distance from the bomb. This picture was made at the Pediatric Clinic of the Kyushu Imperial University during August 1945. No other data are available. (Photo File #NP 125b.)

Fig. 35 (5N)--Maekawa, 32, Female. 1700 meters. This patient was inside a wooden house and received minor wounds and radiation injury. Epilation commenced 20 August, and this photograph was made between that date and 1 September when severe symptoms developed. Omura Naval Hospital Case No. 3100. (Photo File #NP 107b.)

Fig. 36 (5N)--Maekawa, 32; Female. 1700 meters. This is the same patient as in Fig. 35 (5N). This picture was made 11 October, approximately 6 weeks later. There is no evidence of regrowth of hair at this time. The patient was still quite weak due to radiation injury, but she ultimately recovered. Omura Naval Hospital Case No. 3100. (Photo File #NP 107a.)

Fig. 37 (5N)--Inaba, 22. Male. 900 meters. This patient was inside a wooden building and received many lacerations by glass fragments as well as radiation injury. The photograph shows epilation and healing wounds of the scalp. He was convalescent from the effects of radiation at the time the picture was made. November 1945. Omura Naval Hospital Case No. 3069. (Photo File #NP 155 (k).)

Fig. 38 (5N)--Bise, 6. Female. 1100 meters. This patient was inside a wooden house and received only a small burn of the occipital region. The bullae that can be seen in this picture on the shoulders, arms, and legs developed about 27 August. Epilation commenced about the same time. Some of the blisters became infected and she entered hospital 5 September, the day the picture was taken. Omura Naval Hospital Case No. 3049. Japanese Photograph. (Photo File #NP 130.)

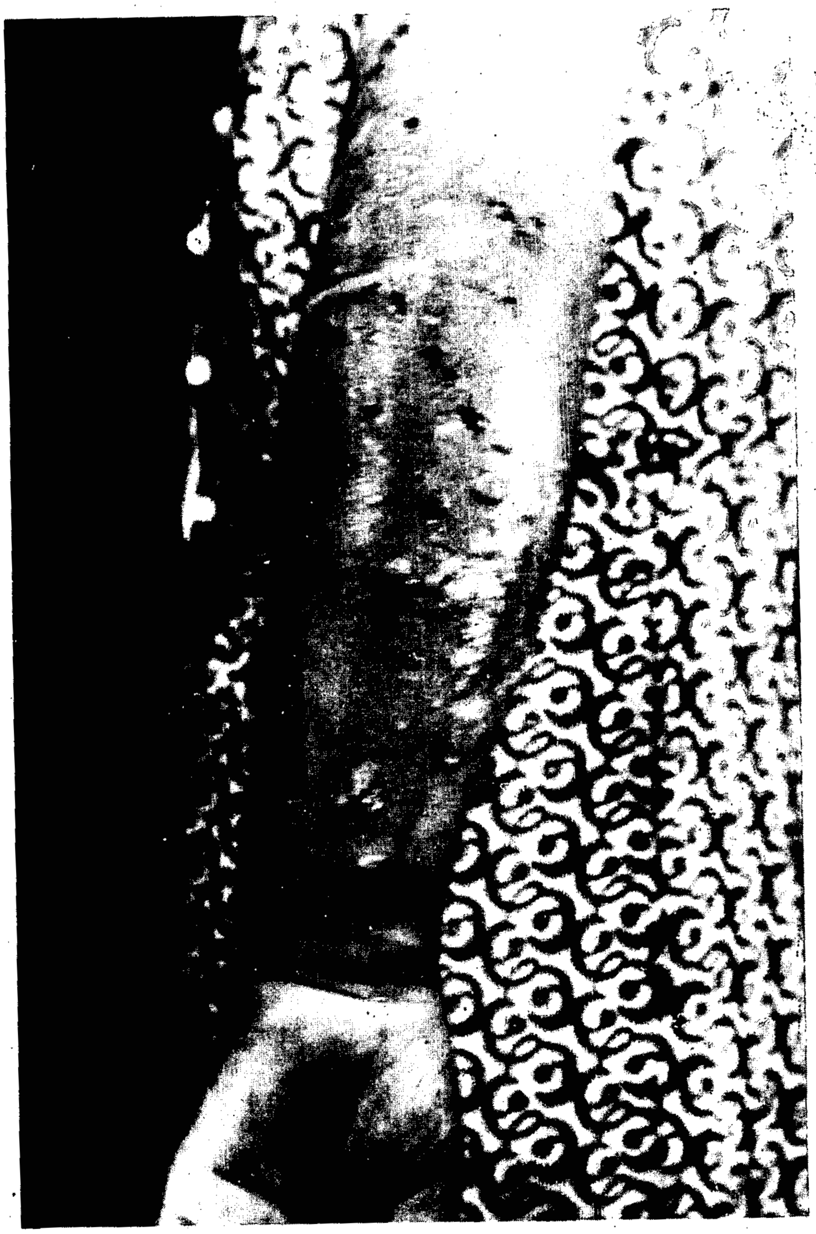


Fig. 39 (5N)--Illustration from a Japanese report, showing a patient in whose skin erythema and vesicles appeared. The dark spots are healed minor lacerations. Shortly after the appearance of the lesions shown in this Figure and in Figure 40 (5N), she developed high fever, purpura, and died 10 days later. Minami report--Appendix 4N (10). Kyushu Imperial University Case. (Photo File #NP 133a.)

Fig. 40 (5N)--Same patient as in Fig. 39 (5N), showing erythema and vesicles of the skin over the knee. Kyushu Imperial University Case. (Photo File #NP 133b.)

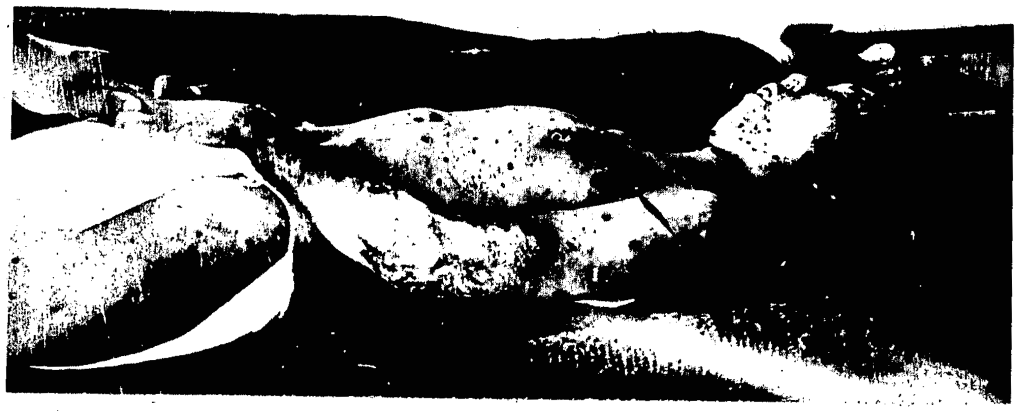


Fig. 41 (5N)--Photograph of unidentified female cadaver made by the Japanese in mid-August. Notice the purpura and the hemorrhagic and necrotic lesions, some of which were said to have been bullous initially. Omura Naval Hospital Case. (Photo File #NP 152.)

Fig. 42 (5N)--Photograph of a child showing cutaneous purpura in an early stage. This picture was taken at the Kyushu Imperial University. The child was said to have been injured in Nagasaki, but no other data were available. (Photo File #NP 126.)

Fig. 43 (5N)--Photograph of a patient with purpura. This picture was made at the Kyushu Imperial University. The patient was said to have been injured in Nagasaki, but no other data were available. (Photo File #NP 128.)

Fig. 44 (5N)--Akiyama, 60. Female. 500 meters. Purpuric lesions of the skin of the legs of a moribund patient. This women had the severe type of radiation injury and died 4 days after this picture was made. 11 October 1945. Omura Naval Hospital Case No. 3098. (Photo File #NP 105a.)

Fig. 45 (5N)--Photograph of an unidentified body, made by the Japanese, in August 1945. Notice the purpuric lesions and the echtymatous ulcerations around wounds which were said to be glass fragment wounds. The patient was said to have died from radiation injury. Omura Naval Hospital Case. (Photo File #NP 127.)

Fig. 46 (5N)--Painting by the medical artist of Kyushu Imperial University of a typical example of "anemic retinitis." See Appendix 4N (8). (Photo File #NS 308 (K).)

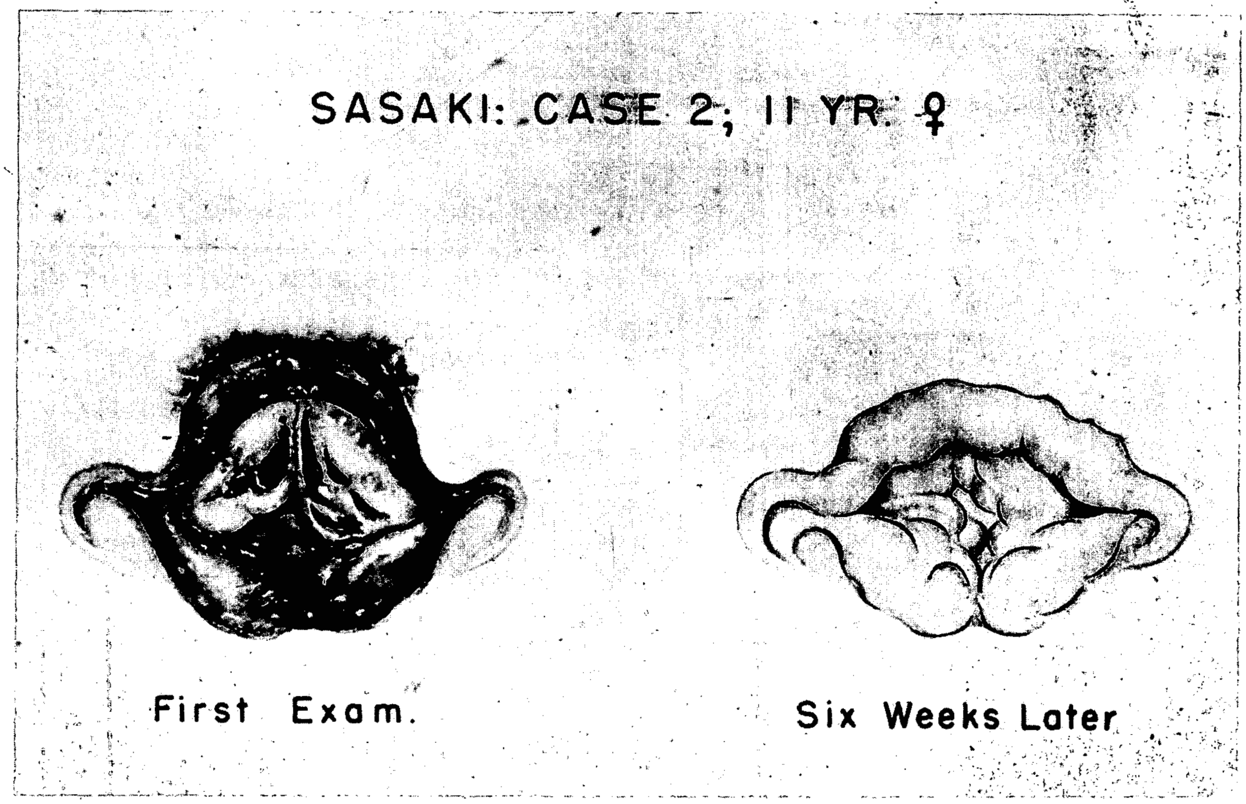


Fig. 47 (5N)--Nagata, N. 11. Female. 1000 meters. Painting by Japanese medical artist of Kyushu Imperial University showing necrotic ulceration of the larynx associated with severe leukopenia and the condition of the healed lesion. Recovery occurred after tracheotomy. See Appendix 4N (9). (Photo File #NS 310 (K).)

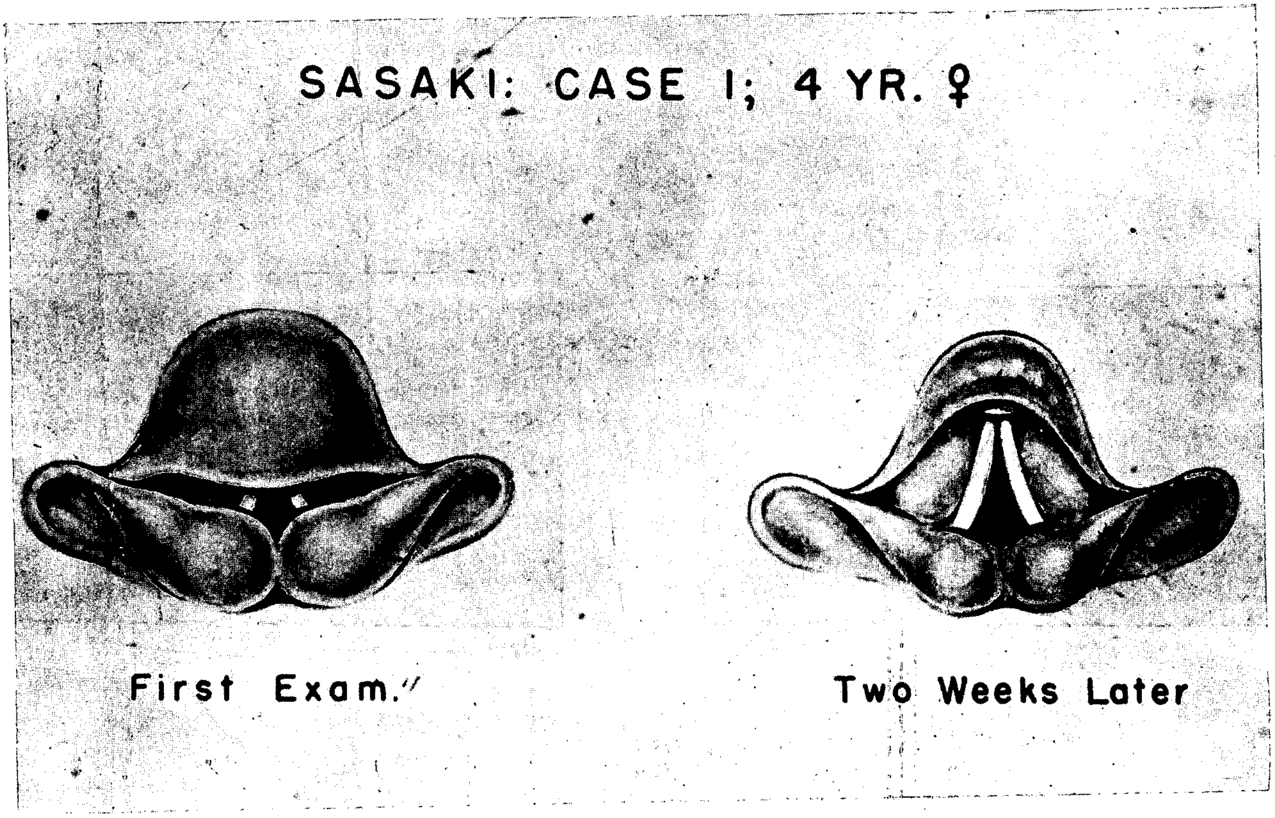


Fig. 48 (5N)--Nagata, Y. 4. Female. 1000 meters. Painting by Japanese medical artist of Kyushu Imperial University showing edema of the larynx associated with severe leukopenia. This patient is the sister of the one illustrated in Fig. 47 (5N). Recovery occurred after tracheotomy. See Appendix 4N (9). (Photo File #NS 309 (K).)

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Armed Forces Institute of Pathology,
Washington, D.C.
MEDICAL EFFECTS OF ATOMIC BOMBS - THE REPORT OF THE JOINT COMMISSION FOR THE INVESTIGATION OF THE EFFECTS OF THE ATOMIC BOMB IN JAPAN - AND APPENDIXES - VOLUME II, by Ashley W. Oughterson, George V. LeRoy, Averill A. Liebow, and others. 19 April' 51, 346 pp. incl. photos, tables, graphs.

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II. LeRoy, George V.
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